# City of Greenbrier

# *PROPOSED*
# Storm Water Quality Design Manual

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# 1.0 INTRODUCTION

This manual presents an introduction to storm water quality Best Management Practices (BMPs) for commercial and industrial development in Greenbrier, Tennessee. It provides guidance in selecting BMPs and contains general fact sheets for each type of BMP to be used. If additional options and more detailed technical information is needed for the selection of BMPs, it is suggested that you refer to the *Best Management Practices section of the Stormwater Management Manual for the Metropolitan Government of Nashville and Davidson County, Tennessee*. This manual was initiated due to requirements in the City of Greenbrier National Pollutant Discharge Elimination System (NPDES) Municipal Separate Storm Sewer (MS4) Phase II permit issued by the Tennessee Department of Environment and Conservation (TDEC) and the City's storm water ordinance.

Certain industries, depending on SIC Codes or narrative descriptions that characterize their activities, as defined in the federal regulation 40 CFR 122.26(b)(14)(i)—(xi) are required to get an Industrial Storm Water General Permit from the Tennessee Department of Environment and Conservation (TDEC) Division of Water Pollution Control. Industries that have no exposure of industrial materials and activities to storm water can submit a no exposure certification in lieu of an NPDES permit.

The intent of this manual is to provide guidance on BMP selection, design, implementation, and plan submitters, reviewers, construction site operators, and site inspectors. There is special emphasis on post construction storm water quality treatment devices for activities at commercial and industrial facilities.

The fact sheets are used as quick references for design, inspection, and maintenance guidance. They are designed to be stand-alone documents that may be distributed to facilitate focused discussion about design and/or implementation of the management practices.

For years, municipalities have been addressing storm water quantity (drainage and flooding) and in recent years have addressed water quality control in the construction phase of projects. The City is now requiring that storm water quality management techniques be applied to new commercial and industrial development in the form of permanent structural BMPs. Storm water quality management involves pollutant identification, control, capture and/or treatment. Some of the pollutants are referred to as "point sources" and appear in the form of regulated discharges, spills, dumping, illicit connections, etc. This manual briefly discusses minimizing the chance of unregulated point sources occurring from storm water runoff.

Point source pollution comes in the form of particulate or dissolved pollutant matter being picked up by storm water runoff over surfaces and conveyed to the City's MS4, creeks, sinkholes, and waterways. Pollution is most prevalent in runoff from small very frequent storm events. Typically these events are less than 1.25 inches of rainfall and that fact was used in the selection, sizing, approach, and maintenance criteria presented in the BMP fact sheets. Design rainfall to be utilized for projects within the City limits is a three month peak flow intensity of 2.5 inches per hour. This is the equivalent of approximately 1.1 inches of runoff depth.

Pollutants of concern include nutrients, metals, pesticides, oil and grease, fuels, other toxic chemicals, and miscellaneous wastes. These pollutants originate from a variety of activities including paving operations, litter, materials storage, automobile fuel, and other daily activities or site (commercial or industrial) management. By conducting an activities inventory, the owner can identify potential pollutant sources and then select appropriate BMPs to address these sources.

***Nutrients***
Phosphorus and nitrogen from fertilizers, pesticides, construction chemicals, and solid waste are often generated by site activities. These nutrients can result in excessive or accelerated growth of vegetation or algae resulting in impaired use of water in lakes and other sources of water supply through taste and odor problems. Excess algae can also deplete dissolved oxygen levels resulting in fish kills. Collectively, the problems associated with excessive levels of nutrients in a receiving stream are referred to as eutrophication impacts.

***Oxygen Demanding Substances***
Lower dissolved oxygen (DO) levels are often the cause of fish kills in streams and reservoirs. The degree of DO depletion is measured by biochemical oxygen demand (BOD) test that expresses the amount of easily oxidized organic matter present in water. The chemical oxygen demand (COD) test measures all the oxidizable matter present in urban runoff. Lowered BOD is caused by the decomposition of organic matter in storm water that depletes DO. Other non-organic materials in the water can intensify DO depletion.

***Metals***
Many artificial surfaces (e.g., galvanized metal, paint, or preserved wood) contain metals that can enter storm water as the surfaces corrode, flake, dissolve, decay, or leach. However, significant portions of metals contained in urban runoff are from cars and trucks. Over half the trace metal load carried in storm water is associated with sediments to which these eroded metals attach. Heavy metals are of concern because they are toxic to aquatic organisms, can be bioaccumulative, and have the potential to contaminate drinking water supplies.

***Pesticides***
Herbicides, insecticides and rodenticides (collectively termed pesticides) are commonly used on contruction sites, lawns, landscapes, parks, golf courses, etc. Unnecessary, excessive, or improper application of these pesticides may result in direct water contamination, indirect water pollution b y aerosol drift, or erosion of treated soil and subsequent transport into surface waters.

***Oil, Grease and Fuels***
These products are widely used and can be spilled/leaked/dumped on the ground where they can be carried by storm water into waterways. Sources include leakage during normal vehicle use, hydraulic line failure, spills during fueling, and inappropriate disposal of drained fluids. These products can cause harm to plant and animal life.

***Other Toxic Chemicals***
Often synthetic organic compounds (adhesives, cleaners, sealants, solvents, etc.) are widely applied and may be improperly stored and disposed. Accidental spills and leakage or deliberate dumping of chemicals onto the ground or into storm drains causes environmental harm in receiving waters.

***Miscellaneous Wastes***
Miscellaneous wastes include wash water from concrete mixers, paints and painting equipment cleaning activities, solid organic wastes resulting from trees and shrubs removed during land clearing, wood and paper materials derived form packaging of building products, food containers, such as paper, aluminum, and metal cans, industrial or commercial process wash/cooling water, vehicle washing, other commercial or industrial wastes and sanitary wastes. The discharge of these wastes can lead to unsightly and polluted receiving waters.

## 2.0 BEST MANAGEMENT PRACTICES

Permanent structural BMPs should be selected and designed by a licensed professional engineer and submitted to the City's Codes department for review. The developer is responsible for proper construction. Prior to beginning site development plans, the Codes department will determine whether permanent BMPs are required.

Currently post development water quality controls are not required for residential subdivisions unless required by the Codes Department.

However, the City encourages the use of landscaping for subdivisions, grassy swales, existing vegetation preservation, infiltration, disconnected roof drains, etc. in order decrease directly connected imperviousness and improve the quality of storm water runoff.

Permanent post development BMPs are designed to control long-term storm water pollution. Permanent BMPs are normally selected in the planning phase of a project and final design as part of the completed submittal to the City. Occasionally, unforeseen natural or manmade factors may require revisions to or additions of permanent BMPs during the construction phase.

During construction, the contractor must ensure that BMPs are installed properly and that any maintenance that may be necessary during construction is performed. After the project is complete it will then be the responsibility of the private or public owner (or other entity formally identified) to provide for long term operation and maintenance. Interim and final maintenance requirements and responsibility should clearly be stated on the contract plans. A maintenance agreement must be submitted to the City.

Operators of construction sites involving clearing, grading, or excavation that result in an area of disturbance of one or more acres, and activities that result in the disturbance of less than one acre if it is part of a larger common plan of development or sale are required to obtain coverage under the TDEC Division of Water Pollution Control General Permit for Storm Water Discharges associated with construction activities (CGP). A copy of the notice of coverage shall be submitted to the Codes Department or designee prior to land disturbing activity.

In addition to the CGP, no land disturbing activity, whether temporary or permanent, shall be conducted within the City until a land disturbance permit has been issued by the Codes Department or designee allowing such activity pursuant to provisions of the City's storm water ordinance, or pursuant to the CGP.

The minimum standards for controlling erosion and sedimentation from land disturbance activities shall be set forth in the latest version of the Tennessee Erosion and Sediment Control Handbook as developed and amended from time to time by TDEC.

## 3.0 BMP SELECTION PROCESS

### 3.1 Define BMP Objectives

Each project is unique; therefore, an understanding of the pollution risks is essential for selecting and implementing BMPs. Defining these requires review of the characteristics of the site; long term function of the site; and impacts of storm water runoff from the site to receiving water bodies. This information should be assembled prior to final design. Once these pollution risks are defined, BMP objectives should be developed. BMP objectives can be identified as follows:

- ***Practice Good Housekeeping***: Perform daily activities in a manner which keeps potential pollutants from either draining or being transported off-site by managing pollutant sources. An example would be to keep site/parking lot trash to a minimum. This will reduce the effort in maintenance of structural BMPs.

- ***Contain Waste***: Dispose of all on site waste in designated areas.

- ***Storm Water Conveyance***: Design site such that storm water runoff is conveyed to water treatment devises prior to being discharged off site.

- ***BMP Efficiency***: Selection of BMP should be based upon performance and efficiency with regard to expectations of future pollutant loading and potential impacts to receiving water bodies.

### 3.2 Identify BMP Categories

Once the BMP objectives are defined, the category of BMPs that are best suited to meet each objective should be identified.

To determine where to place BMPs, a map of the project site can be prepared with sufficient topographic detail to show existing and proposed drainage patterns and proposed permanent storm water BMPs. The project site map should identify the following:

- Locations where storm water enters and exits the site. Include both sheet and channel flow for the existing and final grading contours.

- Identify wetlands, springs, sinkholes, floodplains, floodways, sensitive area or buffers which must not be disturbed, as well as other areas where site improvements will not be constructed.

- Identify the boundaries of tributary areas for each outfall location. Then calculate the approximate contributing drainage area of each tributary at each outfall.

- Define areas where activities have a likely risk of storm water pollutant discharges.

Permanent and temporary BMPs can then be selected and located on the site development plans.

### 3.3 Selection of Permanent Treatment Practices

Most permanent BMPs will be proposed by the developer early in the planning stage of a project. For some projects a single BMP may not address the long-term storm water quality problems. Instead, a multi-level strategy may need to be worked out with the City. Information on a variety of common BMPs is available in Appendix A - Best Management Practices of this manual.

In most cases permanent BMPs can be implemented most effectively when they can be integrated into other aspects of the project design. This requires that conceptual planning consider storm water controls rather than as an afterthought to site design. The following should be considered early in the design process:

- Is a detention/retention facility required for flood control? Often, facilities are required to maintain peak runoff at predevelopment levels to reduce downstream conveyance system damage and other costs associated with flooding. Most permanent BMPs can be incorporated into flood control detention/retention facilities with modest design refinements and limited increases in land area and cost.

- Planned open space which will be relatively flat (e.g., final grade slopes less than 5 percent) may be merged with storm water quality/quantity facilities. Such integrated, multi-use areas may achieve several objectives at a modest cost.

- Infiltration BMPs may serve as groundwater recharge facilities, detention/retention area may be created in landscaped areas of the project, and vegetated swales/filters may be used as roadside/median or parking lot median vegetated areas. Bio-filter and bioretention areas are encouraged wherever possible.

When proprietary structural storm water BMP systems are used as a form of treatment or in a treatment train, the developer must provide the City of Greenbrier with manufacturers information to prove that the system meets the performance standards for water quality final treatment listed in the *Section 3.3.1, Independent Laboratory Data.* Certain "hot spots" (i.e., site sources with concentrated quantities of oil, grease fuels, and other pollutants) may require additional or specific treatment trains as determined by the City.

### *3.3.1 Independent Laboratory Data*

Documentation demonstrating 80% capture of particles in a size range of 2 mm (very coarse sand) to 0.125 mm (very fine sand). Documentation shall include, at a minimum, weight of initial sample washed into the device, and weight of the captured material. Specific gravity of material shall be reported. No particles larger than 2 mm shall be introduced during the test. Gradation curves shall be provided on a split sample of the material washed into the device, and on the capture material. The gradation curves shall demonstrate effective TSS capture to 0.125 mm averaging 80% during test runs. The test will be conducted on full-scale units at design flows.

### *3.3.2 Field Test Data*

Field testing shall include influent and effluent composite samples from a minimum of eight storms. The testing and documentation must demonstrate an 80% removal efficiency for the range of particles listed under Independent Laboratory Data. Particles larger than 2 mm will not be included in the 80% removal calculation. The testing and analysis must be conducted by an independent testing laboratory. Documentation shall demonstrate that the system design prevents scour and re-suspension of particles already collected in the system. Submittals will be reviewed on a case-by-case basis. The following criteria will be used to screen for industrial pollutant-type BMPs.

- More than 400 parking spaces.
- More than 1 acre of contiguous impervious area.
- Vehicle fueling, repair, or storage.
- Heavy equipment fueling, repair, or storage.
- Commercial facilities with potential exposure of food waste or animal waste.

## 4.0 References

*Metropolitan Nashville/Davidson County Storm Water Management Manual, Volume 4,* 1999 and 2009.

# APPENDIX A

# BEST MANAGEMENT PRACTICES PERMANENT TREATMENT PRACTICES (PTP)

## Introduction

This section presents the BMP fact sheets for Permanent Treatment Practices (PTP). PTPs are intended to treat stormwater runoff in the long-term. Some of these BMPs can be designed to achieve both stormwater quantity and quality management objectives.

This section contains the following BMP fact sheets.

| | |
|---|---|
| PTP – 01 | Permeable Pavements |
| PTP – 02 | Bioretention |
| PTP – 03 | Water Quality Swales |
| PTP – 04 | Dry Detention |
| PTP – 05 | Filter Strips |
| PTP – 06 | Grass Channels |
| PTP – 07 | Gravity (Oil-Grit) Separators |

Each fact sheet has a quick reference guide indicating what pollutant constituents the BMP is targeting and implementation requirements. The BMPs presented in this section are intended to serve as permanent treatment measures.

The BMPs found in the PTP section are listed in Table 1. BMPs have been categorized as either General Application or Limited Application BMPs. General Application BMPs meet the post- construction water quality program's pollutant reduction goal by themselves, if designed, built, and maintained according to the supplied specifications. On the other hand, Limited Application BMPs may only be suitable for some sites for one or more reasons: 1) they do not meet the pollutant reduction goal of 80 percent TSS removal 2) they are only suitable for sites with certain conditions 3) they require intensive and or frequent maintenance in order to function properly.

Since some BMPs do not have established removal data, and new structural BMPs are being introduced in to the market every year, the City of Greenbrier has established a set of testing standards, requirements and protocol in order that qualifying devices may be added to Greenbrier's pre-approved BMP list. These requirements can be found in section 3.3 of this manual.

| **Structural Stormwater Control Removal Efficiency for Total Suspended Solids (TSS)** | |
|---|---|
| **Structural Control** | **TSS Removal (%)** |
| **General Application Structural Stormwater Controls** | |
| Bioretention Area | 80 |
| Water Quality Swales | 80 |
| **Limited Application Structural Stormwater Controls** | |
| Filter Strip | 50 |
| Grass Channel | 50 |
| Permeable Pavement | 50 |
| Gravity (Oil-Grit) Separator | 40 |
| Dry Detention | 60 |
| Catch Basin Inserts | Based on Testing |
| Proprietary Structural Control | Based on Testing |

## Calculations for BMPs in a Series

BMPs that do not individually meet Greenbrier's pollutant reduction goal, may be used with another BMP to meet the 80 percent TSS removal requirement. That is, water may pass through one treatment device, into another in a "treatment train" to achieve added treatment. It is necessary to calculate the cumulative pollutant removal from BMPs in a series with an equation that accounts for the fact that the majority of the heavy (easily removed) suspended pollutants and particulate matter are removed by the first structural control in a series. The runoff that enters the second and subsequent controls contains sediment with much smaller particles, which are more difficult for the control to remove. Thus, the second control has a pollutant removal efficiency that is less than it would ordinarily have. The following equation accounts for the cumulative pollutant removal of BMPs in a series.

***TR* = A + (1- A)*B**

Where:
TR = Total Removal
A = 1st structural control in series
B = 2nd structural control in series

*Notes:*
*1)* When runoff flows from a more efficient structure (one with a higher removal rate) to a less efficient structure (one with a lower removal rate), the cumulative pollutant removal of a structure does not increase. The reason is that a structure with a lower removal efficiency that follows a structure with higher removal efficiency does not have an appreciable effect on cumulative pollutant reduction.

*Example Calculation*

A site is planned to have a manufactured pretreatment device that is approved for a 50% TSS removal credit, followed by a dry detention basin designed, built, and maintained as required by Metro regulations to achieve a 60% removal credit. The calculation is as follows:

***TR*** = AMD + **(1-** AMD**)*** BDD

Where:
TR = Total Removal
AMD = 1st structural control—manufactured device
BDD = 2nd structural control—dry detention basin

TR = 0.5 + (1-0.5)*0.6
TR = 0.5 + (0.5)*0.6
TR = 0.5 + 0.3
TR = 0.8

Total Removal equals 80%. The site meets Metro's requirements of 80% TSS removal for the site.

## Permeable Pavements

**Description:** Infiltration practices that are alternatives to traditional asphalt and concrete surfaces. Stormwater runoff is infiltrated into the ground through a permeable layer of pavement or other stabilized permeable surface.

**Variations:** Options range from poured-in-place, specially formulated concrete and asphalt that have greater void space than ordinary pavement to systems of interlocking modular pavers cast with void spaces.

### Components:
- Open graded pavement mix or pavers with open surfaces
- Settling layer
- Open-graded base material
- Filter fabric
- Underdrain (where required)
- Subgrade with *minimal* compaction

### Advantages/Benefits:
- Reduces runoff volume, attenuates peak runoff rate and outflow
- Reduces slick surfaces during rain
- Water quality enhancement from filtration of stormwater

### Disadvantages/Limitations:
- Sediment-laden runoff can clog pervious pavement, causing it to fail
- Constant pressure in the same spot (constant vehicle braking) can collapse pores, causing pavement to fail
- Incorrect installation practices can clog pores

### Design considerations:
- Same basic considerations as any paved area (soil properties, load-bearing design, hydrologic design of pavement & subgrade)
- Infiltration rate of native soil determines appropriateness and need for underdrain
- Not appropriate for heavy or high traffic areas
- Accessibility, aesthetics, maintainability

### Installation considerations:
- Proper installation is crucial to ensure proper functioning
- Subgrade **cannot** be overly compacted
- Construction must be sequenced to avoid compaction and clogging pavement

### Selection Criteria:

- ☐ **Water Quality 80 % TSS Removal**
- ☐ **Accepts Hotspot Runoff**
- ☑ **Residential Subdivision**
- ☑ **High Density / Ultra Urban Use**

### Maintenance:

- Vacuum or jet wash to increase pavement life and avoid clogging
- Ensure that contributing area is clear of debris and sediment.

**M** — **Maintenance Burden**

L = Low M = Moderate H = High

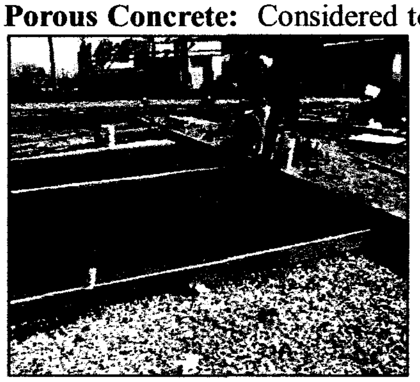
## General Description

**Permeable pavements** are surfaces that can be driven over while permitting rapid infiltration of water into the underlying soil. Constructed of alternative paving materials, permeable pavements are used to locally infiltrate rainwater and reduce the runoff leaving a site. This can decrease downstream flooding, the frequency of combined sewer overflow (CSO) events, and the thermal pollution of sensitive waters. Use of these materials can also eliminate problems with standing water, provide for groundwater recharge, control erosion of streambeds and riverbanks, facilitate pollutant removal, and provide for a more aesthetically pleasing site.

Permeable pavements can be applied in areas that experience low vehicular traffic including parking lots and overflow parking areas; portions of streets such as residential parking lanes; driveways; plazas; and pedestrian or golf cart paths. There are several different forms of permeable pavements, varying from a permeable layer of paving material to grid systems. Four different types of permeable surfaces are discussed below.

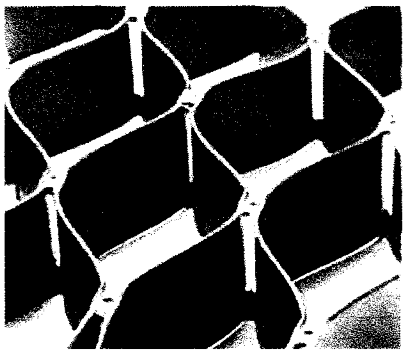
**Porous Asphalt:** Porous asphalt differs from dense asphalt in its use of open-graded aggregate. Because no fine aggregate fills the voids between the single-sized particles, the material is porous and permeable. Porous asphalt can have a porosity of 15%-20%. A surface of porous asphalt is typically placed over a layer of open-graded gravel and crushed stone, with an underlying layer of permeable soil. There are several modifications to the standard design that can be used to increase storage capacity or pass larger flows, including the installation of a perforated pipe in the gravel sublayer, adding a layer of sand, etc.

**Porous Concrete:** Considered to be more durable than porous asphalt, porous concrete is a mixture of open-graded aggregate, which creates the voids in the structure, and Portland cement. The void space in porous concrete is in the 15%-22% range compared to 3%-5% for conventional pavements. Porous concrete is thought to have a greater ability than porous asphalt to maintain its porosity in hot weather. The permeable surface of porous concrete is typically installed as the top of several permeable layers, similar to the installation of porous asphalt described above.

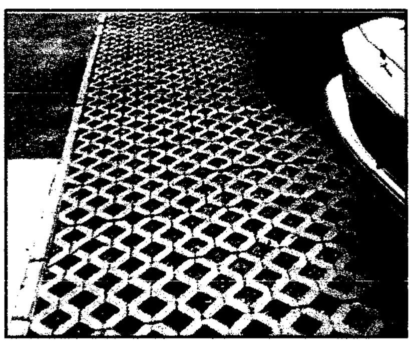


## General Description (Continued)

**Plastic Grid Systems:** These systems are often referred to as *geocells* and are defined by manufactured plastic lattices or mattresses that form networks of box-like cells that are filled with earth material. The lattice is typically 1-2 inches thick and the cells are a few inches wide. Porosity and permeability of these systems is entirely dependent on the cells' fill and vegetation. Like any other pavement surface, geocells require a firm gravel base that provides strength and storage capacity as runoff infiltrates. Geocells are lightweight and easy to transport and install. However, they may similarly be jarred easily by moving traffic.



**Open-Celled Paving Grids:** Commonly called *block pavers or grid pavers*, these grids are structural units, such as concrete blocks or bricks with regularly interdispersed voids that penetrate their entire thickness. Grids are made of concrete or brick and the open cells are filled with porous aggregate or vegetated soil. Block pavers are more rigid and therefore can bear larger traffic loads than plastic grid systems.



**Pollutant Removal Capabilities**

As they provide for the infiltration of stormwater runoff, permeable pavements trap particulate pollutants and absorb some soluble pollutants. Due to the potential for clogging, porous pavements must not be used for the removal of sediment or other coarse particulate pollutants.

**Components**

Several options exist for the top layer or surface of permeable pavements and should be chosen depending on strength required due to traffic loads, infiltration needs, and the manufacturers' recommendations. However, the sub layers are generally similar, consisting of four to five layers as shown in Figure 1.1. The aggregate reservoir layer can sometimes be avoided or minimized if the sub-grade is sandy and there is adequate time to infiltrate the necessary runoff volume into the sandy soil without by-passing the water quality volume. Descriptions of each of the layers are presented below:

*Permeable Pavement Layer* – This layer consists of a porous mixture of concrete or asphalt or a modular pavement grid of plastic, concrete, or brick and an aggregate or a vegetation medium. This layer is usually 2 to 4 inches deep depending on required bearing strength, pavement design requirements, and manufacturer's specifications.

*Settling Layer* – This layer consists of a 0.5-inch diameter crushed stone to a depth of 1 to 2 inches. This layer serves to stabilize the porous asphalt or concrete layer. Can be combined with reservoir layer using suitable stone.

*Reservoir Layer or Open Graded Base Material* – The reservoir gravel base layer consists of washed, bank-run gravel, 1.5 to 2.5 inches in diameter with a void space of about 40%. The depth of this layer depends on the desired storage volume, which is a function of the soil infiltration rate and void spaces, but typically ranges from two to four feet. The layer must have a minimum depth of nine inches. The layer should be designed to drain completely in 48 hours and should be designed to store, at a minimum, the water quality volume ($WQ_v$). Aggregate contaminated with soil must not be used.

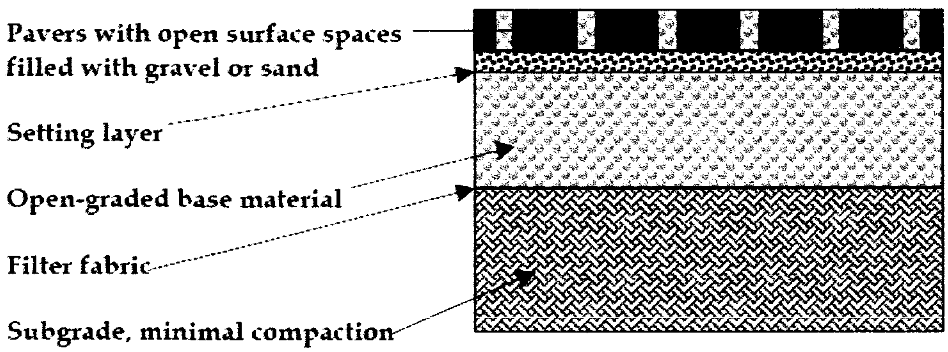
*Bottom Filter Layer (not shown in diagram)* – In cases where infiltration needs to be increased, a 6 inch layer of sand or a 2 inch thick layer of 0.5 inch crushed stone can be installed. The layer should be completely flat to promote infiltration across the entire surface. This layer serves to stabilize the reservoir layer, to protect the underlying soil from compaction, and act as the interface between the reservoir layer and the filter fabric covering the underlying soil.

**Components (Continued)**

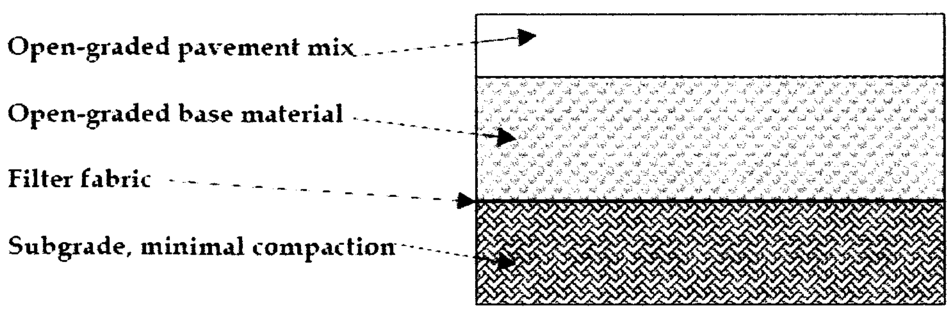
*Filter Fabric* – It is very important to line the entire trench area, including the sides, with filter fabric prior to placement of the aggregate. The filter fabric serves to inhibit soil from migrating into the reservoir and reducing storage capacity.

*Underlying Soil* – The underlying soil should have an infiltration capacity of at least 0.5-inches/hour but preferably greater than 0.5-inches/hour. Soils at the lower end of this range may not be suited for a full infiltration system or may require additional infiltration measures such as a perforated pipe or additional sand layer. Test borings are recommended to determine the soil classification, seasonal high ground water table elevation, and impervious substrata, and an initial estimate of permeability.

Pervious Concrete Block or "Paver" Systems




Pervious (Open Graded) Concrete and Asphalt Mixes




(Source: City of Portland, Oregon, Stormwater Management Manual)

**Figure 1.1 Permeable Pavement Layers**

## Site and Design Considerations

When designing permeable pavement systems, the infiltration rate of the native soil is a key element in determining the depth of base rock for the storage of stormwater, or for determining whether an underdrain system is appropriate. Traffic loading and design speed are important considerations in determining which type of pervious pavement surface is applicable. Pedestrian ADA accessibility, aesthetics, and maintainability are also important considerations.

The following design and site considerations must be incorporated into sites using permeable pavements:

1. The in-situ subsoils should have a high infiltration rate. Permeable pavements are appropriate for all soil types, but will require underdrain systems for soils that do not infiltrate well - hydrologic soil group D or most group C soils, or soils with a high (>30%) clay content. During construction and preparation of the subgrade, special care must be taken to avoid compaction of the soils.
2. Because even infiltration is important, the slope of the site should be less than 10% in all cases, but are not recommended to be more than 2%. Specifications are product-specific and shall comply with manufacturer's recommendations. Barriers perpendicular to the direction of drainage should be installed in sub-grade material to keep it from washing away, or filter fabric should be placed at the bottom and sides of the aggregate to keep soil from migrating into the aggregate and reducing porosity.
3. Porous pavements should only receive runoff from impervious areas. Runoff containing sediment will clog the porous paver surface.
4. Permeable pavements should not be used on sites with a likelihood of high oil or grease concentrations.
5. Not for use in drinking water aquifer recharge areas.

During construction, **do not** overly compact the soil, and avoid installing pavement during extremely high or low temperatures.

Porous paver system designs must use some method to convey larger storm event flows to the conveyance system. One option is to use storm drain inlets set slightly above the elevation of the pavement. This would allow for some ponding above the surface, but would accept bypass flows that are too large to be infiltrated by the porous pavement or if the system clogs.

## As-Built Certification Considerations

After the porous pavement has been installed, an as-built inspection and certification must be performed by a Professional Engineer. See Appendix B. The as-built certification must include verification of the infiltration rates of the porous pavement in addition to other design components that ensure the proper performance of the BMPs.

## Maintenance

Each BMP must have an Operations and Maintenance (O&M) agreement submitted to The City of Greenbrier for approval and maintained and updated by the BMP owner. Refer to Appendix B for the Operation and Maintenance Agreement. The O&M Agreement must be completed and submitted to The City of Greenbrier with the site plans. The O&M agreement is for the use of the BMP owner in performing routine inspections. The developer/owner is responsible for the cost of maintenance and annual inspections. The BMP owner must maintain and update the BMP operations and maintenance plan.

The burden of maintenance is fairly low for permeable pavements. However, failure to maintain and to abide by design and construction standards often results in failure of the measure.

Permeable pavements should be inspected regularly to ensure that the porous surface is free of sediment and that the surrounding area does not have the potential to contribute sediment-laden runoff. The surface should be vacuum swept, followed by high-pressure hosing to keep pores free of sediment. The adjacent, contributing area should be inspected to ensure that it is free of debris and litter, stabilized and mowed, and that clippings have been removed. It would be beneficial to inspect the system during a rain event to ensure that it is dewatering appropriately.

### References

ARC, 2001. Georgia Stormwater Management Manual Volume 2 Technical Handbook.

City of Portland, OR, 2004. Stormwater Management Manual.

CDM, 2000. Metropolitan Nashville and Davidson County Stormwater Management Manual Volume 4 Best Management Practices.

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### Suggested Reading

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Claytor, R.A., and T.R. Schueler. 1996. Design of Stormwater Filtering Systems. The Center for Watershed Protection, Silver Spring, MD.

US EPA, 1999. Storm Water Technology Fact Sheet: Modular Treatment Systems. EPA 832-F-99-044. Office of Water.

Federal Highway Administration (FHWA), United States Department of Transportation. Stormwater Best Management Practices in an Ultra-Urban Setting: Selection and Monitoring. Accessed January 2006. http://www.fhwa.dot.gov/environment/ultraurb/index.htm

## Bioretention Areas

**Description:** Shallow detention area that employs engineered soils and plants to capture and treat runoff.

**Variations:** Bioretention areas can be designed as "raingardens," small bioretention areas that serve individual lots or that can be installed in parking lot planting areas or in depressed areas receiving runoff from paved areas.

### Components:
- Pretreatment - for coarse sediments that would quickly clog area.
- Ponding area – for water quality treatment through settling and chemical processes
- Soils – water quality treatment through chemical processes and filtering; supports plants
- Mulch – water quality treatment through biological processes; conserves soil moisture between rain events to support plants
- Plants – water quality treatment through biological treatment, plant up-take and filtering
- Spillway system – provides outlet for stormwater runoff when large storm events occur and prevents long-term ponding in planting area

### Advantages/Benefits:
- Easily incorporated into new development
- High community acceptance
- Good for highly paved areas such as parking lots
- Good for small drainage areas

### Disadvantages/Limitations:
- Sediment-laden runoff can clog soils in bioretention area
- Requires detailed landscape planning
- Not appropriate for steep slopes
- Relatively expensive

### Design considerations:
- Maximum drainage area of 5 acres, 2 acres maximum impervious
- Typically requires 5 feet of head
- Underlying soils must have good infiltration or must be replaced
- Underdrain system may be needed to keep planting area from ponding water too long

### Selection Criteria:

- ✓ **Water Quality 80 % TSS Removal**
- ✓ **Accepts Hotspot Runoff**
- ✓ **Residential Subdivision**
- ✓ **High Density / Ultra Urban Use**

### Maintenance:
- Replace mulch as needed to maintain depth of mulch
- Replace plant material as needed
- Replace soil if it becomes clogged
- Clean spillway system(s)

**M** **Maintenance Burden**

L = Low M = Moderate H = High

## General Description

Bioretention areas, sometimes known as rain gardens, are structural stormwater controls that capture and temporarily store the $WQ_v$ while using soils and vegetation in landscaped areas to remove pollutants from stormwater runoff. Bioretention areas are engineered facilities in which runoff is conveyed as sheet flow to the "treatment area," consisting of a grass buffer strip, ponding area, organic or mulch layer, planting soil, and vegetation. An optional sand bed can be included in the design to provide aeration and drainage of the planting soil. The filtered runoff is typically collected and returned to the conveyance system, though it can be exfiltrated into the surrounding soil in areas with porous soils.

There are numerous design applications, both on- and off-line, for bioretention areas. These include use on single-family residential lots (rain gardens), as off-line facilities adjacent to parking lots, along highways and road drainage swales, within larger landscaped pervious areas, and as landscaped islands in impervious or high-density environments. However, the structures are not designed to serve as regional stormwater BMPs.

Bioretention facilities can provide a limited amount of water quantity control, with the storage provided by the facility included in the design of any downstream detention structures. However, bioretention areas should be designed so that larger flows bypass them.

Bioretention areas are designed for intermittent flow and to drain and aerate between rainfall events. Sites with continuous flow from groundwater, sump pumps or other areas are not acceptable for bioretention areas.

## Components

Figure 2.1 illustrates a bioretention area. Bioretention areas consist of:

1. Grass filter strip between the contributing drainage area and the ponding area;
2. Ponding areas containing vegetation with a planting soil bed,
3. Organic/mulch layer,
4. Planting soil and vegetation, and
5. Gravel and perforated pipe underdrain system to collect runoff that has filtered through the soil layers (bioretention areas can optionally be designed to infiltrate into the soil).

Optional design components include:
1. Sand filter layer to spread flow, filter runoff and aid in aeration and drainage of the planting soil;
2. Stone diaphragm at the beginning of the grass filter strip to reduce velocities and spread flow into the grass filter;
3. Inflow diversion or an overflow structure.

## Site and Design Considerations

The following design and site considerations must be incorporated into the BMP plan including bioretention areas:

1. The drainage area (contributing or effective) must be 5 acres or less, though 0.5 to 2 acres is preferred.
2. The minimum size for facility is 200 $ft^2$, with a length to width ratio of 2:1. Slope of the area immediately adjacent to the facility must be no more than 20%, but must be more than 2% to ensure proper drainage.
3. The planting soil filter bed is sized using a Darcy's Law equation with a filter bed drain time of 48 hours and a coefficient of permeability (k) of 0.5 ft/day. The planting soil bed must be at least 2 feet deep. Planting soils must be sandy loam, loamy sand or loam texture per USDA textural triangle with a clay content rating from 10 to 25 percent. The soil must have an infiltration rate of at least 0.5 inches per hour and a pH between 5.5 and 6.5. In addition, the planting soil should have a 1.5 to 3 percent organic content and a maximum 500-ppm concentration of soluble salts. For bioretention areas using in situ soils, the depth criteria does not apply.
4. The maximum ponding depth in bioretention areas is 6 inches.
5. The mulch layer must consist of 2-4 inches of commercially available fine shredded hardwood mulch or shredded hardwood chips.
6. The sand bed, if used, must be 12-18 inches thick. Sand must be clean and have less than 15% silt or clay content.
7. Pea gravel for the diaphragm and curtain, where used, must be ASTM D 448 size No. 6 (1/8 inches to 1/4 inches).
8. The underdrain collection system must be equipped with 6-inch perforated pipe in an 8-inch gravel layer. The pipe must have 3/8-inch perforations, spaced on 6-inch centers with a minimum of 4 holes per row. The pipe is spaced at a maximum of 10 feet on center, and a minimum grade of 0.5 percent must be maintained. A permeable filter fabric can be placed between the gravel layer and the planting soil bed.
9. The required elevation difference needed from the inflow to the outflow is 5 feet.
10. The depth from the bottom of the bioretention facility to the seasonally high water table must be a minimum of 2 feet.
11. Runoff captured by facility must enter as sheet flow to prevent erosion of the organic or mulch layer. Velocities entering the mulch layer must be between 1 and 2 feet per second.
12. Continuous flow from groundwater, sump pumps or other areas to the bioretention area is prohibited.
13. An overflow structure and a non-erosive overflow channel must be provided to safely pass the flow from the bioretention area that exceeds the storage capacity to a stabilized downstream area. The high flow structure within the bioretention area can consist of a yard drain catchbasin, with the throat of the catchbasin inlet typically 6 inches above the elevation of the shallow ponding area.
14. All components of the BMP must be located within an easement. Access to the BMP must be located within the easement.
15. The area that will house bioretention must not be used as sediment control measure during active construction.

**Landscaping Bioretention Areas**

Landscaping is critical to the performance and function of the bioretention area. A dense and vigorous groundcover must be established over the contributing pervious drainage area before runoff can be diverted into the facility.

1. The bioretention area should be vegetated like a terrestrial forest ecosystem, with an eventual tree canopy, subcanopy of understory trees, scrub layer and herbaceous ground cover. Three species of each tree and shrub type should be planted.
2. The tree-to-shrub ratio should be 2:1 to 3:1. On average, trees should be spaced 8 feet apart. Plants should be placed at regular intervals to replicate a natural forest. Woody vegetation should not be planted at inflow locations.
3. After the trees and shrubs are established, the ground cover and mulch should be established.

Use native plants, selected based upon hardiness and hydric tolerance.

**As-Built Certification Considerations**

After the bioretention area has been constructed, the developer must have an as-built certification of the bioretention area conducted by a registered Professional Engineer. See Appendix B. The as-built certification verifies that the BMP was installed as designed and approved.

The following components are vital to ensure that the bioretention area works properly and they must be addressed in the as-built certification:

1. Pretreatment, such as a grass filter strip, for coarser sediments must be provided to prevent premature clogging of the system. Design guidance for grass filter strips used as pretreatment is provided in PTP-05 Filter Strip.
2. Surrounding drainage areas must be stabilized to prevent sediment from clogging the filter media.
3. Correct ponding depths and infiltration rates must be maintained to prevent killing vegetation.

A mechanism for overflow for large storm events must be provided.

**Maintenance**

Each BMP must have an Operations and Maintenance (O&M) agreement that is submitted to The City of Greenbrier for approval and is maintained and updated by the BMP owner. Refer to Appendix B for the O&M Agreement for bioretention areas. The O&M Agreement must be completed and submitted to The City of Greenbrier with the site plans. The O&M Agreement is to be used by the BMP owner in performing routine inspections. The developer/owner is responsible for the cost of maintenance and annual inspections. The BMP owner must maintain and update the BMP O&M plan. At a minimum, the operations and maintenance plan must require:

1. Inspect and repair/replace treatment components.
2. Remove debris or dead vegetation.

## Design Procedures

Step 1. Compute the Water Quality Volume.

Calculate the Water Quality Volume ($WQ_v$).

$$WQ_v = P \times Rv \times A/12$$

Where:
$WQ_v$ = water quality treatment volume, ac-ft
P = rainfall for the 85th percentile storm event (1.1 in)
Rv = runoff coefficient (see below)
A = site area, acres

$$Rv = 0.015 + 0.0092I$$

Where:
I = site impervious cover, % (for example, 50% imperviousness = 50)

Step 2. Determine if the development site and conditions are appropriate for the use of bioretention area.

See the *Site and Design Considerations* in this section, above.

Step 3. Confirm additional requirements and watershed applicability.

Check with the City of Greenbrier and other agencies to determine if there are any additional restrictions and/or surface water or watershed requirements that may apply to the site.

Step 4. Compute $WQ_v$ flow rate.

The peak rate of discharge for water quality design storm is needed for sizing of off-line diversion structures.

$$Q = C * I * A$$

**Where:**
$Q$ =Peak discharge (cfs) for the 3 month storm
$C$ = Runoff coefficient
$I$ = 2.45 in/hour
$A$ = site area, acres

**Design Procedures (Continued)**

Step 5. Size flow regulator, if needed.

A flow regulator (or flow splitter diversion structure) must be used to divert the $WQ_v$ to the bioretention area.

Size flow regulator to pass the water quality flow rate, computed in Step 4.

Step 6. Determine size of bioretention ponding/filter area.

The required planting soil filter bed area is computed using the following equation (based on Darcy's Law):

**$Af = (WQ_v)\,(df) / [(k)\,(hf + df)\,(tf)]$** where:

Af = surface area of ponding area ($ft^2$)

$WQ_v$ = water quality volume in cubic feet (or total volume to be captured)
df = filter bed depth (2 feet minimum)
k = coefficient of permeability of filter media (ft/day) (must be at least 0.5 ft/day)
hf = average height of water above filter bed (ft)
(typically 3 inches, which is half of the 6-inch ponding depth)
tf = design filter bed drain time (days)
(2.0 days or 48 hours is recommended maximum)

Step 7. Set design elevations and dimensions of facility.

See *Site and Design Considerations* section.

Step 8. Design conveyances to bioretention area.

See Figure 2.2 for examples of conveyance types for different applications.

Step 9. Design pretreatment.

Pretreat with a grass filter strip (on-line configuration) or grass channel (off-line), and stone diaphragm.

**Design Procedures (Continued)**

Step 10. Size underdrain system

See *Site and Design Considerations.*

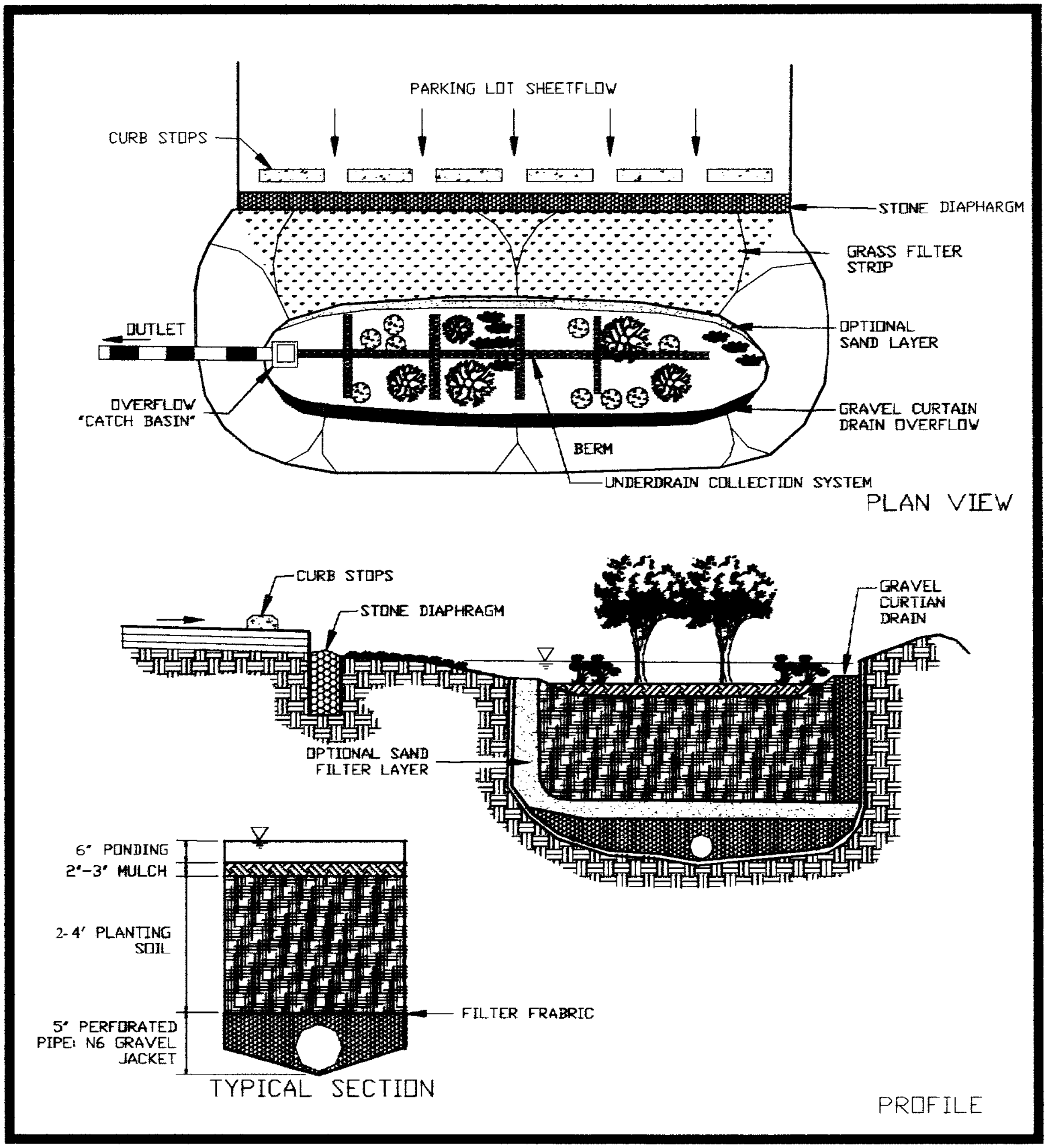
Step 11. Design emergency overflow.

An overflow must be provided to bypass and/or convey larger flows to the downstream drainage system or stabilized watercourse. Non-erosive velocities need to be ensured at the outlet point.

Step 12. Prepare Vegetation and Landscaping Plan.

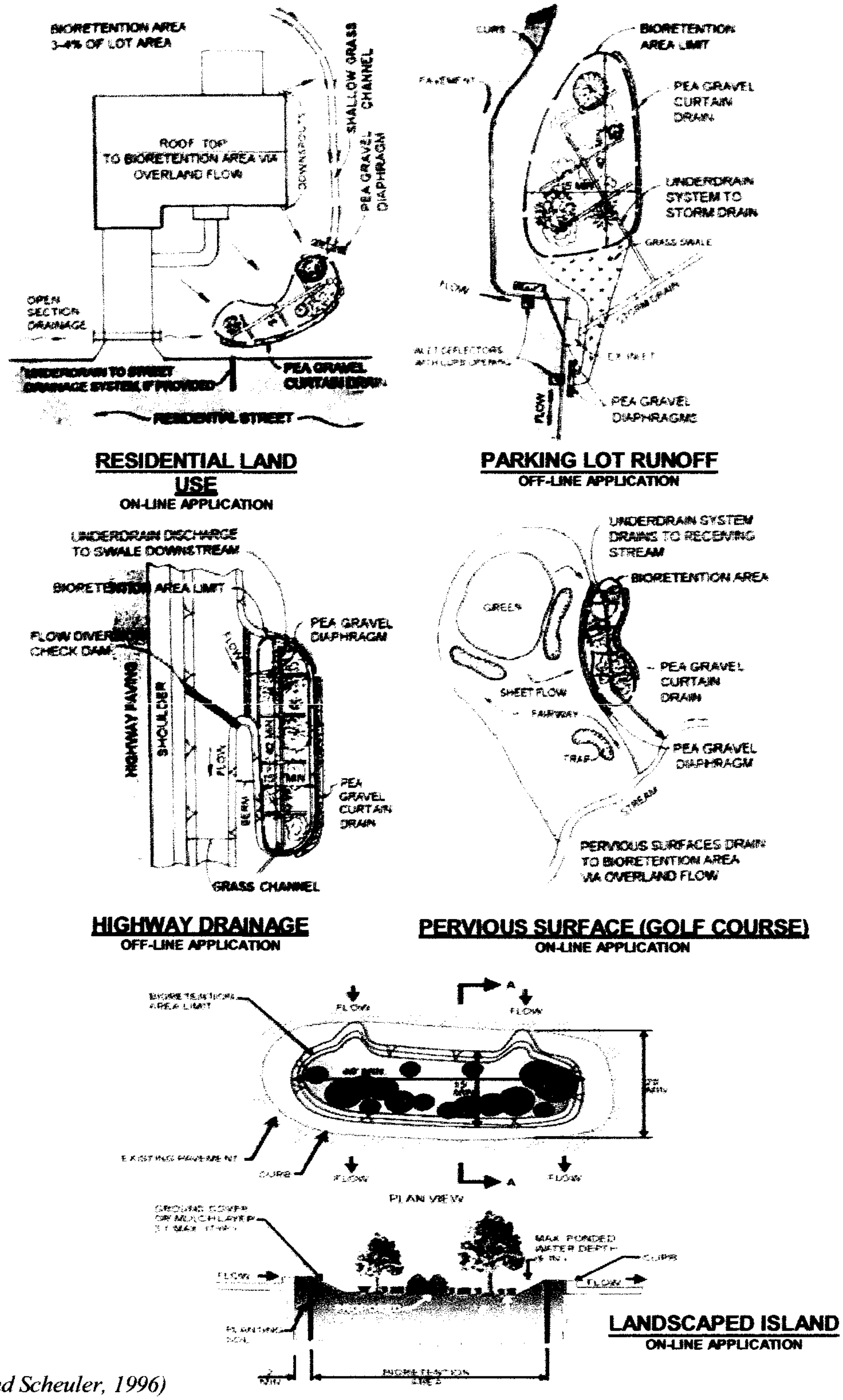
A landscaping plan for the bioretention area should be prepared to indicate how it will be established with vegetation.

See the *Landscaping Bioretention Areas* section for more details.




*(Source: Center for Watershed Protection)*

**Figure 2.1 Bioretention Area**




*(Adapted from Claytor and Scheuler, 1996)*

**Figure 2.2 Applications of Bioretention Areas**

## References

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## Suggested Reading

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## Water Quality Swales

**Description:** Vegetated open channels that are designed to capture and treat stormwater runoff within dry or wet cells formed by check dams or other methods.

**Variations:** Swales can be wet or dry.

### Components:

- Open trapezoidal or parabolic channel sized to store entire $WQ_V$. Dry swale infiltrates full $WQ_V$ and wet swale retains $WQ_V$.
- Filter bed of permeable, engineered soils
- Underdrain system for impermeable soils (dry swale only)
- Wet cells created by check dams (wet swale only)
- Level spreaders every 50 feet, if length exceeds 100 feet.

### Advantages/Benefits:

- Stormwater treatment combined with runoff conveyance
- Less expensive than curb and gutter
- Reduces runoff velocity
- Promotes infiltration

### Disadvantages/Limitations:

- Higher maintenance than curb and gutter
- Cannot be used on steep slopes
- High land requirement
- Vector concerns (wet water quality swale)
- Requires ≈ 3 feet of head

### Design considerations:

- Longitudinal slopes less than 4%
- Bottom channel width of 2 to 8 feet
- Underlying soils must have good infiltration or must be replaced (dry swale)
- Side slopes of 3:1 or flatter; 4:1 recommended
- Convey the 10-year storm event with minimum 6 inches of freeboard.

### Selection Criteria:

- ✓ **Water Quality 80 % TSS Removal**
- ✓ **Accepts Hotspot Runoff** **(impermeable liner required)**
- ✓ **Residential Subdivision**
- ☐ **High Density / Ultra Urban Use**

### Maintenance:

- Maintain grass heights
- Remove sediment from forebay and channel
- Remove accumulated trash
- Re-establish plants as needed

**M** **Maintenance Burden**

L = Low M = Moderate H = High

**General Description**

Water quality swales, also known as "enhanced swales" or vegetated open channels, are channels that capture and treat the water quality volume for a site. They are specifically engineered to perform pollutant removal functions. Water quality swales have specific features that allow them to treat the Water Quality Volume ($WQ_v$). Water quality swales are designed with gradual longitudinal slopes that force runoff to slow down, which allow sediment to settle out while limiting channel erosion. Check dams or other mechanisms are installed perpendicular to the flow to further allow sediment to settle out and runoff to infiltrate.

There are two types of water quality swales, dry and wet:

Dry water quality swales: The dry swale is a vegetated channel that includes a filtering bed of permeable soils overlying an underdrain system. Dry swales are designed to filter or infiltrate the entire $WQ_v$ through this filter bed and underdrain system. Dry swales rely primarily on the filtration mechanism to remove stormwater pollutants. *If it can be demonstrated that the swale can infiltrate the $WQ_v$ within 24 to 48 hours (24 hours is preferred) without an underdrain, the swale may be designed without the underdrain.*

Wet water quality swale: The wet swale is a vegetated channel, also called a wetland channel that acts as a shallow wetland system that retains the $WQ_v$. The channel supports wetland vegetation in shallow marshy conditions. Usually impermeable or poorly drained soils are necessary to support the sufficient retention of water. Wet swales remove pollutants through sediment settling and biological removal. A wet swale does not require an underdrain.

Enhanced swales can be used in a variety of development types; however, they are primarily applicable to residential and institutional areas of low to moderate density where the impervious cover in the contributing drainage area is relatively low. They can also be used along roads and highways. Dry swales are mainly used in moderate to large lot residential developments, small impervious areas (parking lots and rooftops), and along rural highways. Wet swales tend to be used for highway runoff applications, small parking areas, and in commercial developments as part of a landscaped area. Because of their relatively large land requirement, enhanced swales are generally not used in higher density areas. In addition, wet swales may not be desirable for some residential applications, due to the presence of standing water, which may create nuisance odor or mosquito problems.

The topography and soils of a site will determine the applicability of the use of one of the two enhanced swale designs. Overall, the topography should allow for the design of a swale with sufficient slope and cross-sectional area to maintain nonerosive velocities. The following criteria should be evaluated to ensure the suitability of a water quality swale for meeting stormwater management objectives on a site or development.

## Site and Design Considerations

The following design and site considerations must be incorporated into the design for a water quality swale:

**Location:**

1. Channels must be sited so that the longitudinal slope is less than 4%. *Drop structures*, which disrupt flow by producing a pool of water behind them and a short drop in the surface gradient for water flowing over the structure, may be used to reduce the velocity of water in areas with greater slopes. Drop structures include check dams.
2. The water quality swale should have a contributing drainage area of five acres or less to prevent problems with distributing flow evenly across the swale.
3. Wet swales may be used where the water table is very high (at or near the surface of the soil) *or* where the water balance in poorly drained soils will support wetland vegetation.

**General Design:**

4. Both wet and dry water quality swales are designed to treat for water quality, but also to pass larger storms. Runoff enters the channel through a pretreatment forebay. In addition, distributed flow can enter along the sides of the channel after passing through a flow spreader such as a pea gravel diaphragm, level 2 x 12 timbers, or other level spreader along the bank of the channel.
5. <u>Dry water quality swale:</u> consists of an open channel with a filter bed of permeable soils overlaying an underdrain system. Water flows into the channel where it is filtered through the permeable bed. After being filtered, the runoff is conveyed through a perforated pipe and underdrain system to the outlet. A schematic is found in Figure 3.1.
6. <u>Wet water quality swale:</u> consists of an open channel excavated to the water table or to poorly drained soils. Check dams divide the channel into cells. A schematic is found in Figure 3.2.

**Physical Specifications***:*

7. Swales can incorporate raised inlets (4 to 6 inches) to allow for the retention of initial runoff volume.
8. Channel slopes of 1% to 2% and no greater than 4% are recommended. If steeper slopes are necessary, 6 to 12 inch drop structures (see #1 above) can be used to limit runoff energy. Energy dissipators must be installed below drop structures and drop structures must be no closer than 50 feet. The depth of the water at the downstream end of the swale must not exceed 18 inches.
9. Both dry and wet water quality swales must have a bottom channel width of 2 to 8 feet. Wider channels may be installed if designed with berms, walls, or a multi-level cross-section that prevent the channel from meandering and eroding.
10. Cross-sections of dry and wet swales are to be parabolic or trapezoidal with moderate slopes of no greater than 3:1. More gentle slopes of 4:1 are recommended.

**Site and Design Considerations (Continued)**

11. Minimum width should be determined using Manning's equation, with an n of 0.2 to 0.24.
12. Maximum length of the swale shall be 100 feet unless level spreaders are used. Level spreaders shall be placed at least every 50 feet. Maximum length without a level spreader is 80 feet.
13. The maximum ponding depth of the $WQ_v$ must be no greater than 18 inches at the downstream end of the swale. The average ponding depth should be 12 inches.
14. The maximum velocity should be no more than 0.9 feet per second.

**Physical Specifications—Dry Swale:**

15. Dry swale channels are sized to store and infiltrate the entire water quality volume ($WQ_v$) with less than 18 inches of ponding and allow for full filtering through the permeable soil layer. The maximum ponding time is 48 hours, though a 24-hour ponding time is more desirable. Refer to PTP-01 for orifice sizing.
16. The bed of the dry swale consists of a permeable soil layer of at least 30 inches in depth, above a 4-inch diameter perforated pipe (AASHTO Schedule 40) longitudinal underdrain in a 6-inch gravel layer. The soil media should have an infiltration rate of at least 0.5 inches/hour (maximum 0.75 inches/hour) and contain a high level of organic material to facilitate pollutant removal. A permeable filter fabric is placed between the gravel layer and the overlying soil.

**Table 5.1 Infiltration Rates of Common Soil Types**

| Common Soil Types | Infiltration Rates (inches/hour) |
|---|---|
| Coarse Sand | ¾ to 2 |
| Fine Sand | ½ to 1 |
| Fine Sandy Loam | 1/3 to ¾ |
| Silt Loam | ¼ to 4/10 |
| Clay Loam | 1/10 to ¼ |

*(Source: NRCS, USDA www.soils.usda.gov)*

17. The channel and underdrain excavation should be limited to the width and depth specified in the design. The bottom of the excavated trench shall not be loaded in a way that causes soil compaction, and scarified prior to placement of gravel and permeable soil. The sides of the channel shall be trimmed of all large roots. The sidewalls shall be uniform with no voids and scarified prior to backfilling.

**Physical Specifications—Wet Swale:**

18. Wet swale channels are sized to retain the entire water quality volume ($WQ_v$) with less than 18 inches of ponding at the maximum depth point.
19. Check dams can be used to achieve multiple wetland cells. V-notch weirs in the check dams can be utilized to direct low flow volumes.

**Site and Design Considerations (Continued)**

**Pretreatment/Inlets**

20. Inlets to enhanced swales must be provided with energy dissipators such as riprap.
21. Pretreatment of runoff in both a dry and wet swale system is typically provided by a sediment forebay located at the inlet. The pretreatment volume should be equal to 0.1 inches per impervious acre. This storage is usually obtained by providing check dams at pipe inlets and/or driveway crossings.
22. Enhanced swale systems that receive direct concentrated runoff may have a 6-inch drop to a flow spreader at the upstream end of the control.
23. A flow spreader and gentle side slopes should be provided along the top of channels to provide pretreatment for lateral sheet flows.

**Outlet Structures**

24. *Dry water quality swale* underdrain system must discharge to the storm drainage infrastructure or a stable outfall.
25. *Wet water quality swales* must have outlet protection at any outlet so that scour and downstream erosion do not occur.

**Other Considerations**

26. Water quality swales must be designed to safely pass flows that exceed the design storm flows.
27. Maintenance access must be provided for all swales.
28. Landscaping must specify grass species and/or wetland plants that will thrive under the hydric and soils conditions at the particular site.

**As-Built Certification Considerations**

After the water quality swale has been constructed, the developer must have an as-built certification of the swale prepared by a registered Professional Engineer and submit it to The City of Greenbrier. See Appendix B. The as-built certification verifies that the BMP was installed as designed and approved.

The following components must be addressed in the as-built certification:

1. Appropriate underdrain system for dry swales.
2. Correctly sized treatment volume.
3. Poor soils or groundwater table interface for wet swales.
4. Adequate vegetation in place.
5. Overflow system in place for high flows.

**Maintenance**

Each BMP must have an Operations and Maintenance agreement that is submitted to The City of Greenbrier for approval and is maintained and updated by the BMP owner. Refer to Appendix B for the Operation and Maintenance Agreement for swales areas. The O&M Agreement must be completed and submitted to The City of Greenbrier with site plans. The BMP owner must maintain and update the BMP operations and maintenance plan. At a minimum, the operations and maintenance plan must address:

**Maintenance (Continued)**

1. Inspection and repair/replacement of treatment components.
2. Maintain vegetation at heights of 8 inches or less to prevent thinning of vegetative cover, which lessens swale effectiveness.
3. Removal of debris or dead vegetation.

**Landscaping**

*Dry Swale:* Turf grass species appropriate for The City of Greenbrier conditions should be used for dry swale vegetation.

*Wet Swale*: Emergent vegetation should be planted or wetland soils can be spread on the swale bottom for seeding. Where wetland swales do not intercept the groundwater table, a water balance calculation should be performed to ensure that the swale has a water budget adequate to support wetland species.

**Design Procedures**

<u>Step 1. Compute the Water Quality Volume.</u>

Calculate the Water Quality Volume ($WQ_v$), which is the volume that must be stored in the swale.

$$WQ_v = P \times Rv \times A/12$$

Where:
$WQ_v$ = water quality treatment volume, ac-ft
P = rainfall for the 85$^{th}$ percentile storm event (1.1 in)
Rv = runoff coefficient (see below)
A = site area, acres

$$Rv = 0.015 + 0.0092I$$

Where:
I = site impervious cover, % (for example, 50% equals 50)

<u>Step 2. Determine if the development site and conditions are appropriate for the use of an enhanced swale system (dry or wet swale).</u>

See the *Site and Design considerations*, above.

<u>Step 3. Determine pretreatment volume.</u>

The forebay should be sized to contain 0.1 inches per impervious acre of contributing drainage. The forebay storage volume ($F_v$) counts toward the total $WQ_v$ requirement and may be subtracted from the $WQ_v$ for subsequent calculations.

$$F_v = 0.1 \text{ inches} \times A_I \text{ acres} \times .0833$$

**Design Procedures (Continued)**

Where:
$F_v$ = Forebay volume (ac-ft)
$A_I$ = Impervious area of drainage basin, acres
0.0833 = conversion factor of acre inches to acre feet

Often, it is more manageable to work with forebay volumes in cubic feet rather than acre feet, because they are small volumes. To convert $F_v$ in acre feet to cubic feet, multiply $F_v$ by 43560 square feet.

Step 4. Determine swale dimensions.

Size bottom width, depth, length, and slope necessary to store $WQ_v$ with less than 18 inches of ponding at the downstream end.

Channel slope cannot exceed 4% (1% to 2% recommended). For more steeply sloped areas, swale must be "stepped" with check dams or similar structures to maintain slope.

Bottom width should range from 2 to 8 feet

Length to width ratio of 5:1 is suggested.

Ensure that side slopes are no greater than 3:1 (4:1 recommended)

See *Site and Design Considerations*, above.

Step 5. Compute number of check dams or similar structures required to detain $WQ_v$.

Step 6 Calculate drawdown time in the swale.

*Dry Swale:* Planting soil, 30 inches, should pass a maximum rate of 1.5 feet/day and must completely filter $WQ_v$ in 48 hours.

*Wet Swale:* Must hold $WQ_v$.

Step 7 Check 2-year velocity erosion potential and provide 6 inches of freeboard above 10-year storm.

Step 8 Design low flow orifice at downstream headwalls and checkdams.

Design orifice to pass $WQ_v$ in six hours.

.

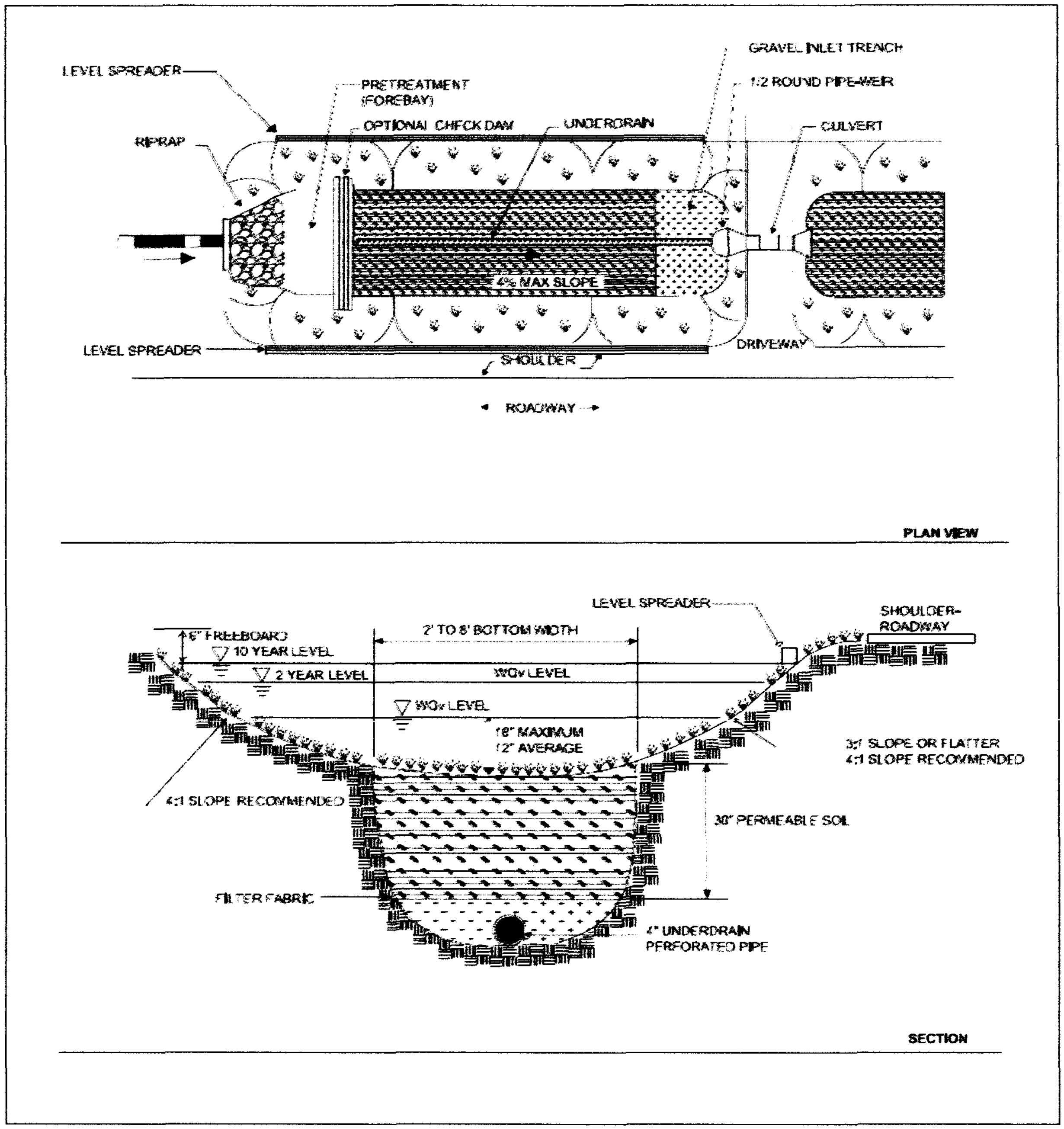
**Design Procedures (Continued)**

Step 9. Design inlets, sediment forebays and underdrain system (dry swale).

See *Site and Design Considerations,* above.

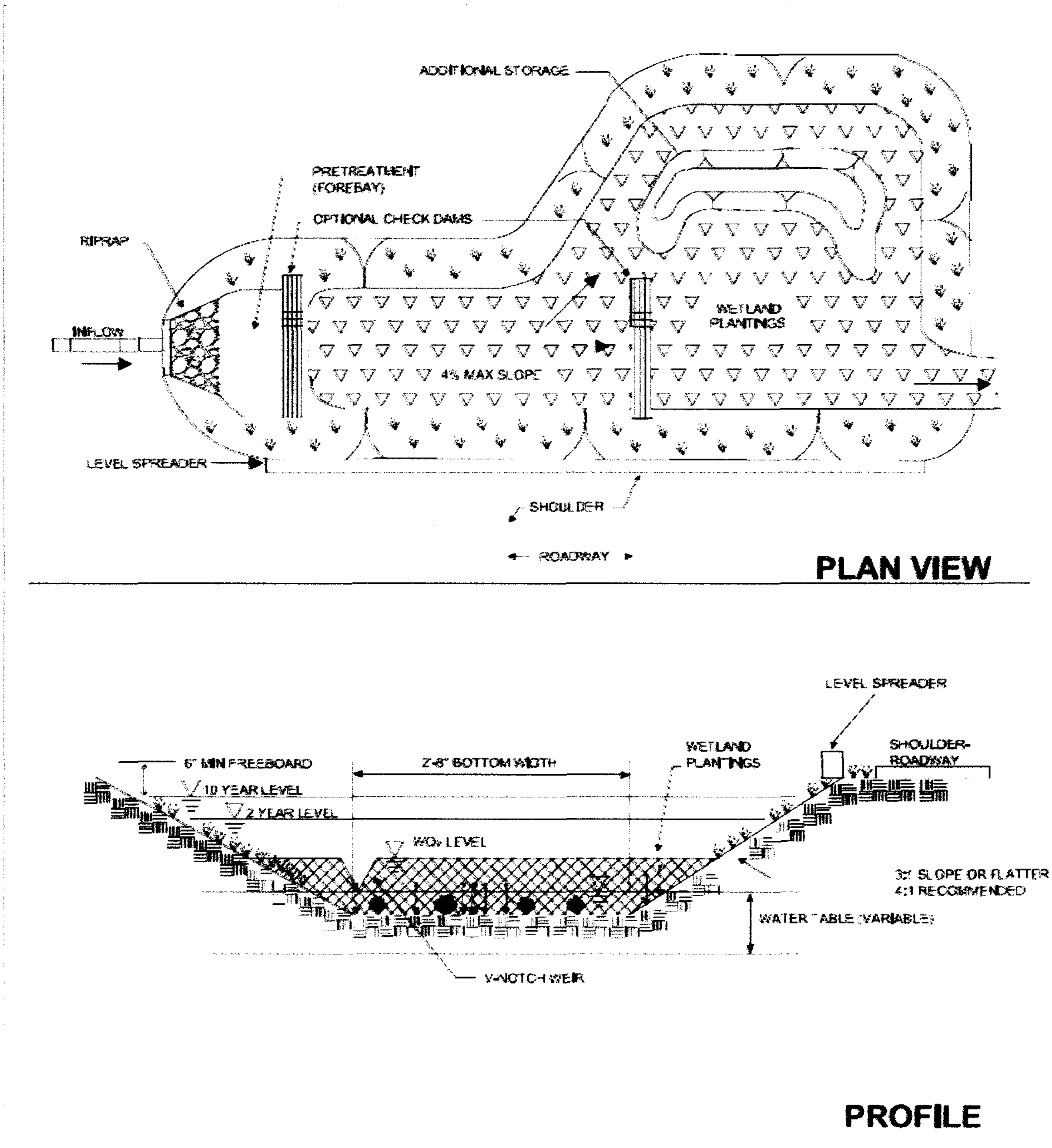
Step 10 Prepare Vegetation and Landscaping Plan.

A landscaping plan for a dry or wet swale should indicate how the enhanced swale system will be stabilized and established with vegetation.



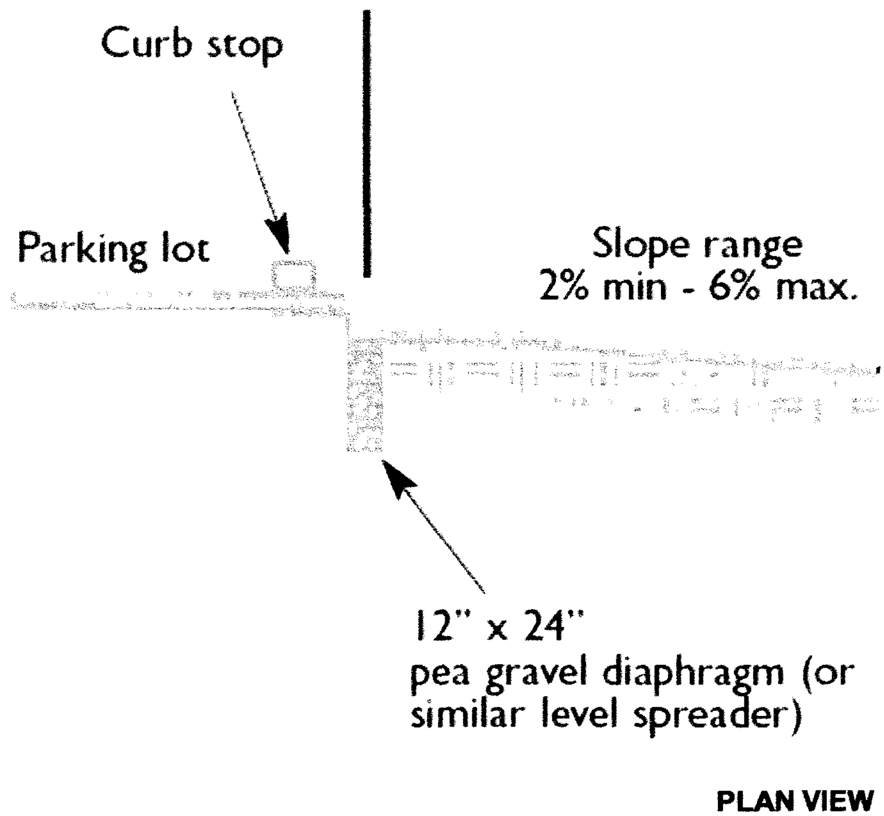

*(Adapted from the Center for Watershed Protection)*

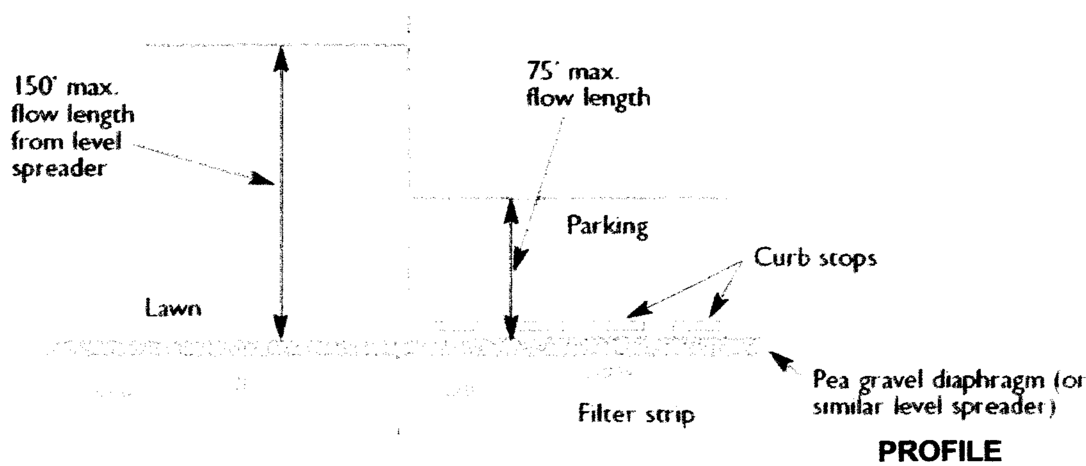
**Figure 3.1 Dry Water Quality Swale**




*(Adapted from the Center for Watershed Protection)*

**Figure 3.2 Wet Water Quality Swale**




*(Source: Connecticut Stormwater Management Manual)*

**Figure 3.3 Example of Level Spreader**
**(for Swales Receiving Directly Connected Runoff)**

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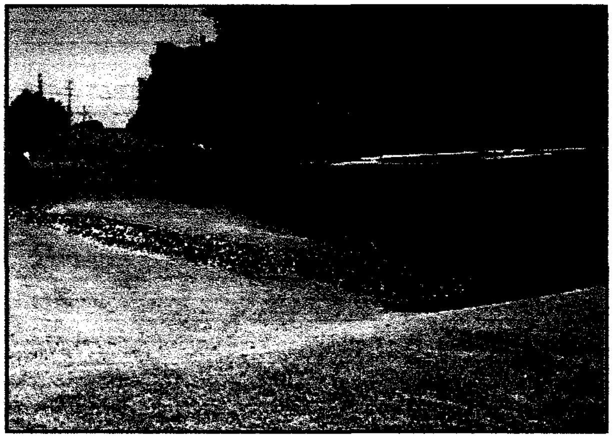
# Dry Ponds



**Description:** A surface storage basin or facility designed to provide water quantity control and limited water quality benefits through detention and/or extended detention of stormwater runoff.

## Components:

- Pool area –fills during a storm and releases water slowly through bottom outlet
- Forebay – settles out larger sediments in an area where sediment removal (maintenance) will be easier
- Spillway system – provides outlet for stormwater runoff when large storm events occur

## Advantages/Benefits:

- Typically less costly than stormwater (wet) ponds for equivalent flood storage, as less excavation is required
- Provides recreational and other open space opportunities between storm runoff events

## Disadvantages/Limitations:

- Controls for stormwater quantity—not intended to provide for total water quality treatment; assumed to achieve 60% TSS removal
- Must be used in conjunction with other water quality controls
- Tends to re-suspend sediment

## Design considerations:

- Applicable for drainage areas up to 75 acres
- Drawdown of 24 to 48 hours
- Shallow pond with large surface area performs better than deep pond of same volume
- Assumed to provide 60% TSS removal

## Selection Criteria:

- ☐ **Water Quality 80 % TSS Removal**
- ☐ **Accepts Hotspot**
- ☑ **Residential Subdivision**
- ☑ **High Density / Ultra Urban Use**

## Maintenance:

- Remove debris from basin surface
- Remove sediment buildup
- Repair and revegetate eroded areas.
- Perform structural repairs to inlet and outlets.
- Mow unwanted vegetation

**L** **Maintenance Burden**

L = Low M = Moderate H = High

## General Description

Dry extended detention (ED) basins, as shown in Figure 4.1, are surface facilities intended to provide for the temporary storage of stormwater runoff to reduce downstream water quantity impacts. These facilities temporarily detain stormwater runoff, releasing the flow over a period of time. They are designed to completely drain following a storm event and are normally dry between rain events. For the purposes of this application, dry detention and dry extended detention are considered the same treatment.

Dry detention basins, when used for flow attenuation, can be designed to control up to the 100-year storm event, the detention requirement for The City of Greenbrier.

Dry detention basins provide limited pollutant removal benefits and are not intended for sole water quality treatment. Detention-only facilities must be used in a treatment train approach with other structural controls that provide treatment of the $WQ_v$. This type of facility is assumed to provide 60% TSS removal. While the ponds may be providing peak flow attenuation in addition to water quality treatment (in-line ponds), the other water quality treatment controls in the treatment train must be <u>off-line</u>.

Compatible multi-objective use of dry detention facilities is strongly encouraged.

## Site and Design Considerations

**Location**

1. Dry detention basins are to be located downstream of other structural stormwater controls providing treatment of the water quality volume ($WQ_v$). See Appendix A Introduction, for more information on the use of multiple structural controls in a treatment train.
2. The maximum contributing drainage area to be served by a single dry detention basin is 75 acres.

**General Design**

3. Dry detention basins can be sized to hold the $WQ_v$ or, if used for flow attenuation, they can be sized to temporarily store the 100-year storm. Routing calculations must be used to demonstrate that the storage volume is adequate for flow attenuation.
4. Tennessee Safe Dams Act may apply to ponds with storage volumes and embankment heights large enough to fall under the regulation.
5. Vegetated embankments shall be less than 20 feet in height and shall have side slopes no steeper than 3:1 (horizontal to vertical). Riprap-protected embankments shall be no steeper than 2:1. Geotechnical slope stability analysis is recommended for embankments greater than 10 feet in height and is mandatory for embankment slopes steeper than those given above. All embankments must be designed to Tennessee state

**Site and Design Considerations (Continued)**

guidelines for dam safety, as applicable.

6. The maximum depth of the basin should not exceed 10 feet.
7. Areas above the normal high water elevations of the detention facility (that is, the largest event for which the facility is sized) should be sloped toward the basin to allow drainage and to prevent standing water. Careful finish grading is required to avoid creation of upland surface depressions that may retain runoff. A low flow or pilot channel across the facility bottom from the inlet to the outlet (often constructed with riprap) is recommended to convey low flows and prevent standing water conditions.
8. Adequate maintenance access must be provided for all dry basins.

**Inlet and Outlet Structures**

9. Inflow channels are to be stabilized with flared riprap aprons, or the equivalent. A sediment forebay sized to 0.1 inches per impervious acre of contributing drainage should be provided for dry detention basins.
10. For a dry detention basin used for flow attenuation, the outlet structure is sized for 100-year peak flow control (based upon hydrologic routing calculations) and can consist of a weir, orifice, outlet pipe, combination outlet, or other acceptable control structure. Small outlets that will be subject to clogging or are difficult to maintain are not acceptable. A low flow orifice capable of releasing the $WQ_v$ over 24 hours must be provided.
11. Seepage control or anti-seep collars should be provided for all outlet pipes.
12. Riprap, plunge pools or pads, or other energy dissipaters are to be placed at the end of the outlet to prevent scouring and erosion. If the basin discharges to a channel with dry weather flow, care should be taken to minimize tree clearing along the downstream channel, and to reestablish a forested riparian zone in the shortest possible distance.
13. An emergency spillway is to be included in the stormwater pond design to safely pass the extreme flood flow. The spillway prevents pond water levels from overtopping the embankment and causing structural damage. The emergency spillway must be designed to State of Tennessee dam safety requirements and must be located so that downstream structures will not be affected by spillway discharges.
14. A minimum of one foot of freeboard must be provided, measured from the top of the water surface elevation for the 100-year storm, to the lowest point of the dam embankment not counting the emergency spillway.

**As-Built Certification Considerations**

After the pond is constructed, an as-built certification of the pond, performed by a registered Professional Engineer, must be submitted to The City of Greenbrier. See Appendix B. The as-built certification verifies that the BMP was installed as designed and approved. The following components must be addressed in the as-built certification:

1. Pretreatment for coarse sediments must be provided.
2. Surrounding drainage areas must be stabilized to prevent sediment from clogging the filter media.
3. Correct ponding depths and infiltration rates must be maintained to prevent killing vegetation.
4. A mechanism for overflow for large storm events must be provided.

**Maintenance**

Each BMP must have an Operations and Maintenance (O&M) Agreement submitted to The City of Greenbrier for approval and maintained and updated by the BMP owner. Refer to Appendix B for the Operation and Maintenance Agreement for dry detention ponds. The O&M Agreement must be completed and submitted to The City of Greenbrier with site plans. The O&M agreement is for the use of the BMP owner in performing routine inspections. The developer/owner is responsible for the cost of maintenance and annual inspections. The BMP owner must maintain and update the BMP operations and maintenance plan. At a minimum, the operations and maintenance plan must address:

1. Inspect and repair/replace treatment components.
2. Perform annual verification of infiltration rates.
3. Remove debris or dead vegetation.

## Design Procedures

Step 1. Compute the Water Quality Volume to Receive 60% TSS Credit.

Calculate ($WQ_v$). *If flow attenuation is not required, the pond can be sized for the $WQ_v$ only.*

$$WQ_v = P \times Rv \times A/12$$

Where:

$WQ_v$ = water quality treatment volume, ac-ft
P = rainfall for the 85% storm event (1.1 in)
Rv = runoff coefficient (see below)
A = site area, acres

$$Rv = 0.015 + 0.0092I$$

Where:
I = site impervious cover, % where 50% is 50

Step 2. Determine if the development site and conditions are appropriate for the use of a dry pond.

Consider the *Site and Design Considerations* previously in this section. This type of treatment must be used in conjunction with another water quality measure in order to achieve 80% TSS removal.

Step 3. Determine pretreatment volume.

A sediment forebay is sized for each inlet, unless the inlet provides less than 10% of the total design storm inflow to the pond. The forebay should be sized to contain 0.1 inches per impervious acre of contributing drainage and should be 4-6 feet deep. The forebay storage volume counts toward the total $WQ_v$ requirement and may be subtracted from the $WQ_v$ for subsequent calculations.

$$F_v = 0.1 \times A_I \times 3630$$

Where:
$F_v$ = Forebay volume ($ft^3$)
$A_I$ = Impervious area of drainage basin, acres
3630 = conversion factor from Ac/in to cubic feet

Step 4. Size the outlets for storm events.

If the pond is to serve as a multifunctional pond addressing peak flow attenuation, the downstream impacts must be considered for the 2- through 100-year events.

**Design Procedures (Continued)**

Establish a stage-storage-discharge relationship for the design storms of interest, based upon the downstream analysis.

Step 5. Size the low flow outlet for the water quality volume.

Size low flow orifice using the following equation. If different equation is used or different type of low flow orifice is used, provide supporting calculations.

$$a = \frac{2A(H - H_o)^{0.5}}{3600CT(2g)^{0.5}}$$

a = area of orifice ($ft^2$)
A = average surface area of the pond ($ft^2$)
C = orifice coefficient, 0.66 for thin, 0.80 for materials thicker than orifice diameter
T = drawdown time of pond (hrs), must be greater than 24 hours
g = gravity (32.2 ft/$sec^2$)
H = elevation when pond in full (ft)
$H_o$= final elevation when pond is empty (ft)

Step 6. Design embankment and emergency spillway.

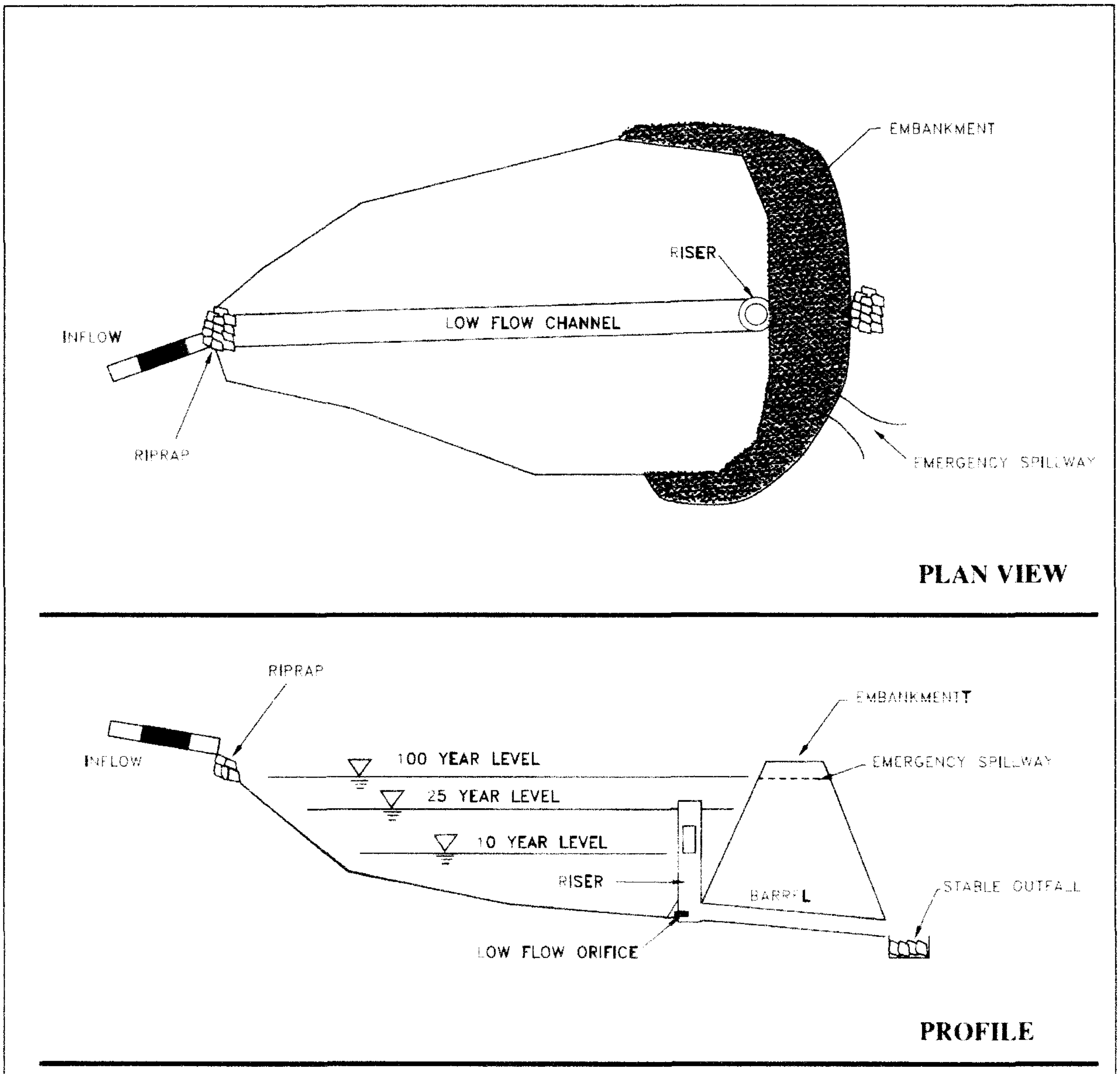
Size emergency spillway for any overtopping of pond in case of rain event in excess of 100-year storm and for instances of malfunction or clogging of primary outlet structure.

Step 7. Investigate potential dam hazard classification.

The design and construction of ponds in Tennessee must follow the requirements of the Safe Dams Act. Contact the Tennessee Department of Environment and Conservation, Division of Water Supply for more information about building dams in Tennessee.

Step 8. Design inlets, sediment forebays, outlet structures, maintenance access and safety features.

See the *Site and Design Considerations* section for information on design.




**Note: Storm attenuation levels vary depending on site detention requirements.**

*(Adapted from the Center for Watershed Protection)*

**Figure 4.1 Schematic of Dry Extended Detention Basin**

### References

ARC, 2001. Georgia Stormwater Management Manual Volume 2 Technical Handbook.

CDM, 2000. Metropolitan Nashville and Davidson County Stormwater Management Manual Volume 4 Best Management Practices.

### Suggested Reading

California Storm Water Quality Task Force, 1993. California Storm Water Best Management Practice Handbooks.

City of Austin, TX, 1988. Water Quality Management. Environmental Criteria Manual. Environmental and Conservation Services.

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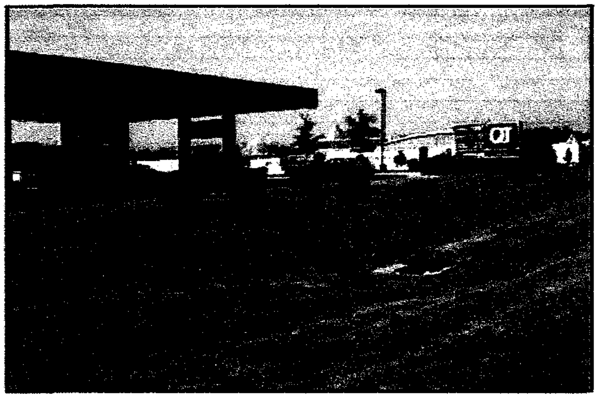
# Filter Strip



**Description:** Uniformly graded section of land that is densely vegetated and is designed to treat runoff through vegetative filtering and infiltration. Water enters the filter strip along its width and runs across the length of the filter strip.

## Components:

- Vegetation – provides water quality treatment through filtering and plant uptake; vegetation can be grasses or other deep-rooted plants
- Land with gradual slope – minimal slopes allow for some amount of water quality treatment through infiltration
- Level spreader – ensures runoff over the vegetated filter is in sheet flow (shallow, uniform flow length) as opposed to concentrated (channelized) flow

## Advantages/Benefits:

- High community acceptance in any type of setting
- Easy to maintain once ground cover and/or trees established
- Can be used as pre-treatment for other BMPs, similar to sediment forebay
- Filter strips are easily incorporated into new construction/ development designs

## Disadvantages/Limitations:

- Cannot meet the 80% total suspended solids goal without another BMP in a treatment train. Fifty foot strip is assumed to achieve 50% TSS removal, while 25 foot strip used as a pretreatment control is assumed to achieve 10% TSS removal
- Filter strip and level spreaders have limited drainage areas
- It can be difficult to construct a level lip on level spreaders

## Design considerations:

- Must have slopes between 2% and 6%
- Must maintain sheet flow across entire filter strip
- Minimum 25 foot flow length; the longer the flow length, the higher the pollutant removal, if sheet flow is maintained.

## Selection Criteria:

- [ ] **Water Quality 80% TSS Removal**
- [x] **Accepts Hotspot Runoff**
- [x] **Residential Subdivision**
- [ ] **High Density / Ultra Urban Use**

## Maintenance:

- Maintain a dense, healthy stand of grass and other vegetation
- Repair erosion
- Periodic sediment removal
- Revegetate as needed

L **Maintenance Burden**

L = Low M = Moderate H = High

## General Description

Filter strips are uniformly graded, densely vegetated areas of land that are designed to remove pollutants from runoff through vegetative filtration and infiltration. Filter strips are suited for treating runoff from roads and highways, small parking lots, pervious areas, and roof downspouts. They are also well-suited as the outer zone of a stream buffer and as pretreatment for other structural controls. Filter strips that fulfill The City of Greenbrier requirements can be used as credits against the stormwater quality volume for a site.

The vegetation can be grassed or a combination of grass and woody plants. Pollutant removal efficiencies are based upon a 50-foot long strip. Filter strips with shorter flow lengths are considered to have lower removal efficiencies and should be used as coarse sediment settling areas for other structural controls. Filter strips are and considered to be an integral component of those controls, similar to sediment forebays. Uniform sheet flow must be maintained through the filter strip to provide pollutant reduction and to avoid erosion. To obtain sheet flow when discharging runoff from a developed area, a level spreader may be required.

## Components

Figure 5.1 illustrates a filter strip. Filter strips consist of the following components:

1. Sheet flow spreader that allows flow to enter the filter strip as sheet flow.
2. Uniformly graded area with 2 to 6 percent slopes, with a minimum width of 15 feet, and a minimum length (flow path) of 50 feet for a 50% TSS removal credit (Appendix A Introduction) and 25 feet for a settling or pretreatment control, with a lesser credit of 10% TSS removal.
3. Dense vegetation that can withstand relatively high velocity flows.
4. Optional berm.

## Site and Design Considerations

The following design and site considerations must be incorporated into the filter strip design:

1. Filter strips should be used to treat small drainage areas, ordinarily with a maximum of 75 feet for impervious surfaces, and 150 feet for pervious surfaces (CWP, 1996). For longer flow paths, special provision must be made to ensure design flows spread evenly across the filter strip. .
2. Flow must enter the filter strip as sheet flow spread out over the width of the strip, generally no deeper than 1 to 2 inches.
3. Filter strips should be integrated into site designs.
4. Filter strips should be constructed outside the natural stream buffer area whenever possible to maintain a more natural buffer along the streambank.
5. Filter strips should be designed for slopes between 2% and 6%. Greater slopes than this would encourage the formation of concentrated flow. Flatter slopes would encourage standing water.
6. Filter strips should not be used on soils that cannot sustain a dense grass cover with high retardance. Designers should choose a grass that can withstand relatively high velocity flows at the entrances, and both wet and dry periods.
7. The filter strip should be at least 15 feet long to provide filtration and contact time for water quality treatment. 25 feet is preferred, though length will normally be dictated by design method. 50 feet is necessary to achieve the 50% TSS removal credit.
8. Both the top and toe of the slope should be as flat as possible to encourage sheet flow and prevent erosion.
9. An effective flow spreader a pea gravel diaphragm located at the top of the slope (ASTM D 448 size no. 6, 1/8" to 3/8"). The pea gravel diaphragm is a small trench running along the top of the filter strip. It serves two purposes. First, it acts as a pretreatment device, settling out sediment particles before they reach the filter strip. Second, it acts as a level spreader, maintaining sheet flow as runoff flows over the filter strip. Other types of flow spreaders include long timbers, a concrete sill, curb stops, or curb and gutter with "sawteeth" cut into it.
10. Ensure that flows in excess of design flow move across or around the strip without damaging it. Often a bypass channel or overflow spillway with protected channel section is designed to handle higher flows.
11. Maximum discharge loading per foot of filter strip width (perpendicular to flow path) is found using the Manning's equation:

$$q = \frac{0.00236}{n} Y^{\frac{5}{3}} S^{\frac{1}{2}}$$

Where: q = discharge per foot of width of filter strip (cfs/ft)
Y = allowable depth of flow (inches)
S = slope of filter strip (percent)
n = Manning's "n" roughness coefficient
(Use 0.15 for medium grass, 0.25 for dense grass, and 0.35 for very dense Bermuda-type grass)

**Site and Design Considerations (Continued)**

12. Using $q$, computed above, The minimum width of a filter strip is:

$$W_{fMIN} = \frac{Q}{q}$$

Where: $W_{fMIN}$ = minimum filter strip width perpendicular to flow (feet)
Q = water quality flow rate (see PTP-02 Bioretention, page 5, Design Step #4).

**Filter Strips without Berm**

13. Size filter strip (parallel to flow path) for a contact time of 5 minutes minimum.
14. Equation for filter length is based on the SCS TR-55 travel time equation (SCS, 1986):

$$L_f = \frac{(T_t)^{1.25}(P_{2-24})^{0.625}(S)^{0.5}}{3.34n}$$

Where: $L_f$ = length of filter strip parallel to flow path (25 ft minimum)
$T_t$ = travel time through filter strip (5 minutes minimum)
P2-24 = 2-year, 24-hour rainfall depth (3.39 inches)
S = slope of filter strip (2-6 percent preferred)
n = Manning's "n" roughness coefficient
(Use 0.15 for medium grass, 0.25 for dense grass, and 0.35 for very dense Bermuda-type grass)

*(Source for equations in items 11 through 14: Georgia Stormwater Management Manual)*

**Filter Strips with Berm**

15. Size outlet pipes to ensure that the bermed area drains within 24 hours..
16. Specify grasses resistant to frequent inundation within the shallow ponding limit.
17. Berm material should consist of sand, gravel and sandy loam to encourage grass cover (Sand: ASTM C-33 fine aggregate concrete sand 0.02"-0.04", Gravel: AASHTO M-43 ½" to 1").
18. Size filter strip to contain the $WQ_v$ within the wedge of water backed up behind the berm.
19. Maximum berm height is 12 inches.

**Filter Strips for Pretreatment**

20. A number of other structural controls, including bioretention areas and infiltration trenches, may utilize a filter strip as a pretreatment measure. The required length of the filter strip depends on the drainage area, imperviousness, and the filter strip slope. Table 5.1 provides sizing guidance for using filter strips for pretreatment. Filter strips used as pretreatment for coarse sediment for bioretention areas and infiltration trenches are not credited with removing TSS above and beyond the main treatment BMP.

## Site and Design Considerations (Continued)

**Table 5.1 Sizing of Filter Strips for Pretreatment Only**

| Parameter | Impervious Areas* | | | | Pervious Areas (Lawns, etc)** | | | |
|---|---|---|---|---|---|---|---|---|
| Maximum inflow approach length (feet) | 35 | | 75 | | 75 | | 150 | |
| Filter strip slope (max = 6%) | < 2% | > 2% | < 2% | > 2% | < 2% | > 2% | < 2% | > 2% |
| Filter strip minimum length (feet)*** | 10 | 15 | 20 | 25 | 10 | 12 | 30 | 36 |

* 75 feet maximum impervious area flow length to filter strip.
** 150 feet maximum pervious area draining to filter strip.
***At least 25 feet is *required* for minimum pretreatment credit of 10% TSS removal. Fifty feet is required for obtaining 50% TSS removal credit.
*(Adapted from Georgia Stormwater Management Manual)*

## As-Built Certification Considerations

After the filter strip has been constructed, the developer must have an as-built certification of the filter strip conducted by a registered Professional Engineer. See Appendix B. The as-built certification verifies that the BMP was installed as designed and approved.

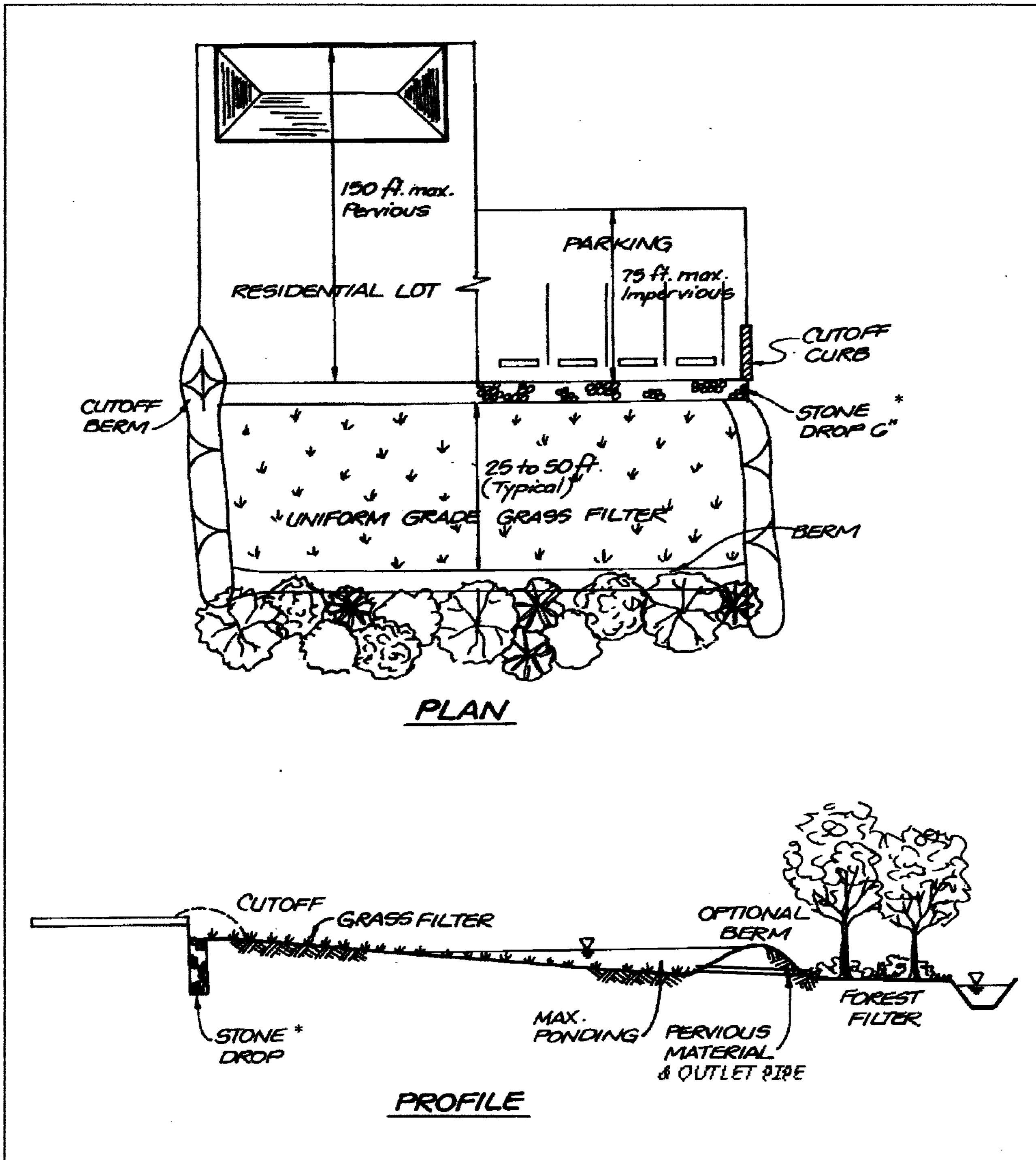
The following components must be addressed in the as-built certification:

1. Ensure design flows spread evenly across filter strip.
2. Ensure design slope is between 2% and 6%.
3. Verify dimensions of filter strip.

## Maintenance

Each BMP must have an Operations and Maintenance (O&M) Agreement that is submitted to The City of Greenbrier for approval and is maintained and updated by the BMP owner. Refer to Appendix B for the Operation and Maintenance Agreement for filter strips. The O&M Agreement must be completed and submitted to The City of Greenbrier with the site plans. The O&M Agreement is to be used by the BMP owner in performing routine inspections. The developer/owner is responsible for the cost of maintenance and annual inspections. The BMP owner must maintain and update the BMP operations and maintenance plan. At a minimum, the operations and maintenance plan must address:

1. Maintain a dense, healthy stand of grass and other vegetation by frequent mowing: grass heights of 3 to 5 inches should be maintained, with a maximum grass height of 8 inches;
2. Repair erosion;
3. Periodic sediment removal; and
4. Revegetate as needed.




(Adapted from Georgia Stormwater Manual)

* Stone drop or some other acceptable type of level spreader to achieve sheet flow.

**Figure 5.1 Filter Strip**

### References

ARC, 2001. Georgia Stormwater Management Manual Volume 2 Technical Handbook.

CDM, 2000. Metropolitan Nashville and Davidson County Stormwater Management Manual Volume 4 Best Management Practices.

### Suggested Reading

California Storm Water Quality Task Force, 1993. California Storm Water Best Management Practice Handbooks.

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## Grass Channels

**Description:** Limited application structural control. Open channels that are vegetated and are designed to filter stormwater runoff, as well as slow water for treatment by another structural control.

### Components:
- Broad bottom channel on gentle slope (4% or less)
- Gentle side slopes (3:1 (H:V) or less)
- Dense vegetation that assists in stormwater filtration
- Check dams can be installed to maximize treatment

### Advantages/Benefits:
- Provides pretreatment if used as part of runoff conveyance system
- Provides partial infiltration of runoff in pervious soils
- Less expensive than curb and gutter
- Good for small drainage areas
- Relatively low maintenance requirements

### Reasons for Limited Use:
- Cannot alone achieve 80% removal of TSS; Fifty foot long channel is assumed to achieve 50% removal of TSS
- Must be carefully designed to achieve low flow rates in the channel (< 1.0 ft/s)
- May re-suspend sediment
- May not be acceptable for some areas because of standing water in channel

### Design considerations:
- Maximum drainage area of 5 acres
- Require slopes of 4% or flatter
- Runoff velocities must be non-erosive
- Appropriate for all but the most impermeable soils
- Requires vegetation that can withstand both relatively high velocity flows and wet and dry periods.

### Selection Criteria:

☐ **Water Quality 80% TSS Removal**

☑ **Pretreatment**

☑ **Residential Subdivision**

☑ **High Density / Ultra Urban Use**

**Other:** Replaces curb and gutter

### Maintenance:
- Mow grass to 3 or 4 inches high
- Clean out sediment accumulation in channel
- Inspect for and correct formation of rills and gullies
- Ensure that vegetation is well-established

$\boxed{L}$ **Maintenance Burden**

L = Low M = Moderate H = High

## General Description

Grass channels, sometimes called biofilters, are conveyance channels that are designed to provide some treatment of runoff, as well as to slow down runoff velocities for treatment in other structural controls. Grass channels are appropriate for a number of applications including treating runoff from paved roads and from pervious areas.

Grass channels do not provide full water quality treatment because they are not designed with engineered filtration areas, as water quality swales (PTP-03) are. Because they are not enhanced for increased filtration and infiltration, they provide a lower TSS removal and are appropriate for limited application in combination with other structural controls.

Grass channels are able to infiltrate some runoff from small storms when situated in pervious soils. They provide other ancillary benefits such as reduction of impervious cover, accenting natural features, and reduced cost when compared with traditional curb and gutter.

The most important considerations when designing a grass channel are the channel capacity and erosion prevention. Runoff velocities must not exceed 1.0 foot per second during the peak discharge associated with the 2-year design storm. In addition, the vegetation height should provide 5 minutes of residence time in the channel.

Figure 6.1 illustrates a grass channel. A grass channel consists of the following elements:

1. A broad bottomed, trapezoidal or parabolic channel on a gentle slope (4% or less);
2. Gently sloping sides (3:1 (H:V) or less);
3. Hardy vegetation that can withstand relatively high velocities as well as a range of moisture conditions from very wet to dry; and
4. Optional check dams to increase residence time.

## Site and Design Considerations

The following design and site considerations must be incorporated into the grass channel design:

**General Considerations**

1. The drainage area (contributing or effective) must be 5 acres or less. Runoff flows and volumes from larger drainage areas prevent proper filtration and infiltration of stormwater.
2. Grass channels should be designed on areas with slope of less than 4%. Slopes of 1% to 2% are recommended.
3. Grass channels can be used on most soils with some restrictions on the most impermeable soils. Grass channels should not be used on soils with infiltration rates less than 0.27 inches per hour if infiltration of small runoff flows is intended.
4. A grass channel should be designed to accommodate the water quality flow. Calculations for the water quality flow are as follows:

   $$Qp = C * I * A$$

   Where:
   Qp = the peak flow through the grass channel in cfs
   C = runoff coefficient
   I = rainfall intensity, 2.45 in/hr
   A = the contributing drainage area for the grass channel in acres

   Larger flows should be accommodated by the channel if dictated by the surrounding conditions. For instance, The City of Greenbrier requires site drainage to accommodate the 100-year design storm.
5. The channel should accommodate the 2-year, 24-hour storm without eroding.
6. Grass channels should have a trapezoidal or parabolic cross section with relatively flat side slopes (generally 3:1 or flatter).
7. The bottom of the channel should be between 2 and 6 feet wide. The minimum width ensures a minimum filtering surface for water quality treatment, and the maximum width prevents braiding, which is the formation of small channels within the swale bottom. The bottom width is a dependent variable in the calculation of velocity based on Manning's equation. If a larger channel is needed, the use of a compound cross section is recommended.
8. Runoff velocities must be nonerosive. The full-channel design velocity will typically govern.
9. A 5-minute residence time is recommended for the water quality peak flow. Residence time may be increased by check dams, reducing the slope of the channel, increasing the wetted perimeter, or planting a denser grass (raising the Manning's n).
10. The depth from the bottom of the channel to the groundwater should be at least 2 feet to prevent a moist swale bottom, or contamination of the groundwater.

## Site and Design Considerations (Continued)

11. Incorporation of check dams within the channel will maximize retention time.
12. Designers should choose a grass that can withstand relatively high velocity flows at the entrances, and both wet and dry periods.
13. A forebay is recommended in order to minimize the volume of sediment in the channel.
14. Provide an overflow for larger storm events.
15. Design of open channel hydraulics shall be considered.

**Grass Channel as Pretreatment**

A number of structural controls such as bioretention areas and infiltration trenches may be supplemented by a grass channel that serves as pretreatment for runoff flowing to the device. The lengths of grass channels vary based on the drainage area imperviousness and slope. Channels must be no less than 20 feet long. Table 6.1 below gives the minimum lengths for grass channels based on slope and percent imperviousness:

**Table 6.1 Grass Channel Length Guidance**
(Source: Georgia Stormwater Management Manual)

| Parameter | <= 33% Impervious | | Between 34% and 66% Impervious | | >= 67% Impervious | |
|---|---|---|---|---|---|---|
| Slope (max = 4%) | < 2% | > 2% | < 2% | > 2% | < 2% | > 2% |
| Grass channel minimum length* (feet) *assumes 2-foot wide bottom width | 25 | 40 | 30 | 45 | 35 | 50 |

## As-Built Certification Considerations

After the grass channel has been constructed, an as-built certification of the grass channel must be prepared by a registered Professional Engineer and submitted to The City of Greenbrier. See Appendix B. The as-built certification verifies that the BMP was installed as designed and approved.

The following components must be addressed in the as-built certification:

1. The channel must be adequately vegetated.
2. The channel flow velocities must not exceed 1.0 foot per second.
3. A mechanism for overflow for large storm events must be provided.

## Maintenance

Each BMP must have an Operations and Maintenance (O&M) agreement that is submitted to The City of Greenbrier for approval and is maintained and updated by the BMP owner. Refer to Appendix B for the O&M Agreement for bioretention areas. The O&M Agreement must be completed and submitted to The City of Greenbrier with the site plans.

Maintenance requirements for grass channels include the following:

1. Maintain grass height of 3 to 4 inches.
2. Remove sediment build up in channel bottom when it accumulates to 25% of original total channel volume.
3. Ensure that rills and gullies have not formed on side slopes. Correct if necessary.
4. Remove trash and debris build up.
5. Replant areas where vegetation has not been successfully established.

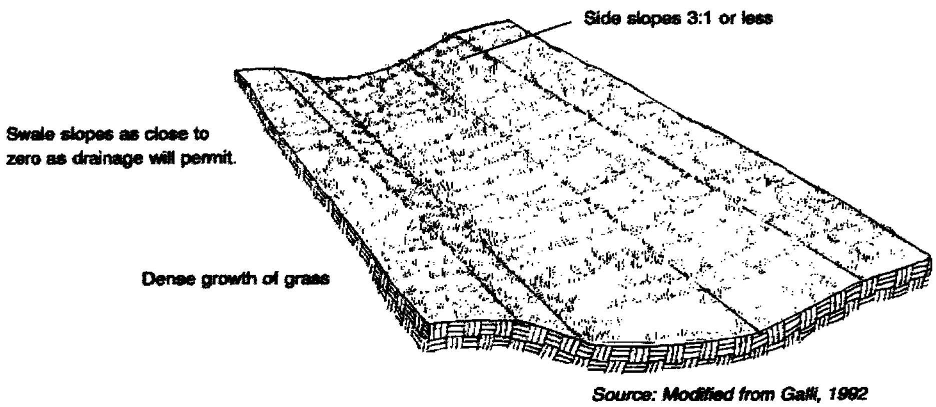
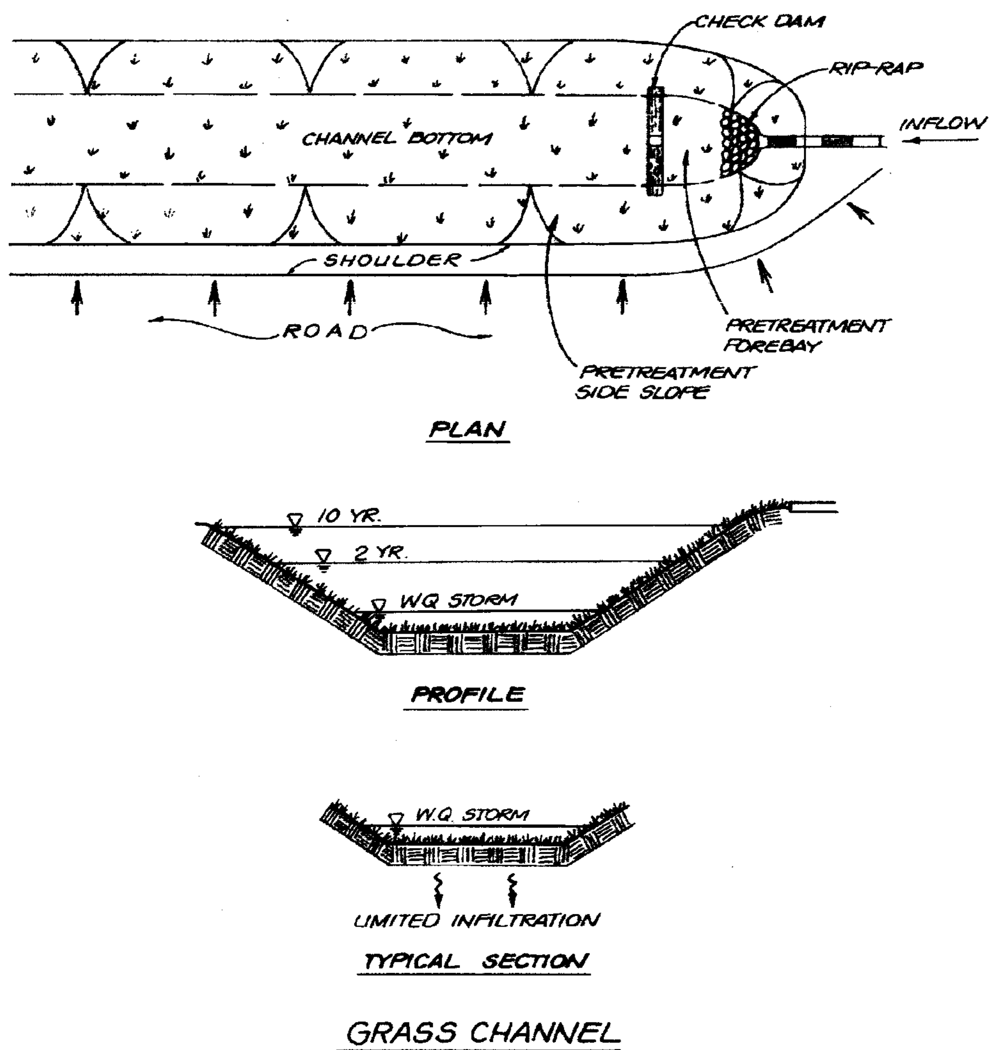



**Figure 6.1 Typical Grass Channel**




*(Source: Center for Watershed Protection)*

**Figure 6.2 Grass Channel Schematic**

## References

ARC, 2001. Georgia Stormwater Management Manual Volume 2 Technical Handbook.

CDM, 2000. Metropolitan Nashville and Davidson County Stormwater Management Manual Volume 4 Best Management Practices.

Claytor, R.A., and T.R. Schueler. 1996. Design of Stormwater Filtering Systems. The Center for Watershed Protection, Silver Spring, MD.

## Suggested Reading

California Storm Water Quality Task Force, 1993. California Storm Water Best Management Practice Handbooks.

City of Austin, TX, 1988. Water Quality Management. Environmental Criteria Manual. Environmental and Conservation Services.

City of Sacramento, CA, 2000. Guidance Manual for On-Site Stormwater Quality Control Measures. Department of Utilities

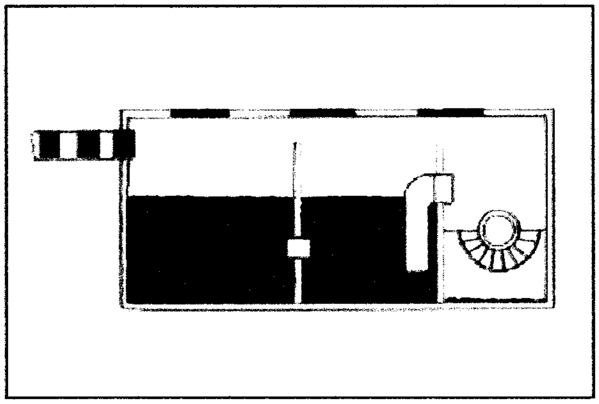
Horner, R.R., 1988, "Biofiltration Systems for Storm Runoff Water Quality Control", Washington State Department of Ecology.

IEP, 1991, "Vegetated Buffer Strip Designation Method Guidance Manual", Narragansett Bay Project.

Maryland Department of the Environment, 2000. Maryland Stormwater Design Manual, Volumes I and II. Prepared by Center for Watershed Protection (CWP).

Metropolitan Washington Council of Governments (MWCOG), March, 1992, "A Current Assessment of Urban Best Management Practices: Techniques for Reducing Nonpoint Source Pollution in the Coastal Zone".

## Gravity (Oil-Grit) Separator



**Description**: Hydrodynamic separation device designed to remove settleable solids, oil and grease, debris and floatables from stormwater runoff through gravitational settling and trapping of pollutants. Facilities with fueling and parking lots containing over 400 spaces require a more advanced separator with coalescing tubes/plates designed to provide a surface that minute oil globules are attracted to and can agglomerate upon. The coalesced oil then rises to the surface to be skimmed.

### Components:
- Inlet chamber
- Separation and oil storage chamber
- Enhanced components such as swirl concentrator chamber and Coalescing filter (in high-risk areas)
- Outlet chamber

### Advantages/Benefits:
- Good for land uses that are hotspots for hydrocarbons
- Pretreatment for water quality
- Coalescing systems can remove oil particles down to the 20 micron range, while conventional device removes down to the 150 micron level.

### Disadvantages/Limitations:
- Cannot alone achieve the 80% TSS removal target
- Intended for hotspot, space-limited or pretreatment applications
- Limited performance data
- Dissolved pollutants are not removed
- Frequent maintenance required

### Design considerations:
- Intended for the removal of settleable solids (grit and sediment) and floatable matter, including oil and grease
- Access point for maintenance required
- Performance dependent on design and frequency of inspection and cleanout of unit
- Openings to device must be 1/16 inch or less to prevent mosquito intrusion and breeding.
- Install as an off-line device unless size of separator can be matched to smaller drainage area
- Install inspection/collection manhole on downstream side to provide easy access for sampling of effluent.

### Selection Criteria:

- [ ] **Water Quality 80 % TSS Removal**
- [x] **Accepts Hotspot Runoff**
- [ ] **Residential Subdivision**
- [x] **High Density / Ultra Urban Use**

### Maintenance:

- Inspect the gravity separator unit
- Clean out sediment, oil and grease, and floatables, using catch basin cleaning equipment (vacuum pumps). Manual removal may be necessary

**H** — **Maintenance Burden**

L = Low M = Moderate H = High

**General Description**

Gravity separators (also known as oil-grit separators) are hydrodynamic separation devices that are designed to remove grit and heavy sediments, oil and grease, debris and floatable matter from stormwater runoff through gravitational settling and trapping. Gravity separator units contain a permanent pool of water and typically consist of an inlet chamber, separation/storage chamber, and an access port for maintenance purposes. Runoff enters the inlet chamber where heavy sediments and solids drop out. The flow moves into the main gravity separation chamber, where further settling of suspended solids takes place. Oil and grease are skimmed and stored in a waste oil storage compartment for future removal. After moving into the outlet chamber, the clarified runoff is then discharged.

In "hot-spot" areas (fueling areas, car washes, large parking lots with over 400 spaces, etc.), separators are required to be equipped with coalescing tubes/plates. These tubes/plates provide a media in which minute oil globules can agglomerate to aid in the separation process. Oil that agglomerates around the coalescing tubes/plates can easily be skimmed through the gravity process.

When used for oil removal, the performance of these systems is based primarily on the relatively low solubility of petroleum products in water and the difference between the specific gravity of water and the specific gravities of petroleum compounds. Gravity separators are not designed to separate other products such as solvents, detergents, or dissolved pollutants. The typical gravity separator unit may be enhanced with a pretreatment swirl concentrator chamber, coalescing tubes/plates, oil draw-off devices that continuously remove the accumulated light liquids, and flow control valves regulating the flow rate into the unit.

Gravity separators are best used in commercial, industrial and transportation land uses and are intended primarily as a pretreatment measure for high-density or ultra urban sites or for use in hydrocarbon hotspots such as gas stations and areas with high vehicular traffic. However, gravity separators cannot be used for the removal of dissolved or emulsified oils and pollutants such as coolants, soluble lubricants, glycols and alcohols, or in waste streams that contain detergents or other chemical-laden wastes.

**Site and Design Considerations**

Since resuspension of accumulated sediments is possible during heavy storm events, gravity separator units are typically installed off-line. Gravity separators are available as prefabricated proprietary systems from a number of commercial vendors.

1. The use of gravity (oil-grit) separators should be limited to the following applications:
   - Pretreatment for other structural stormwater controls

**Site and Design Considerations (Continued)**

- High-density, ultra urban or other space-limited development sites
- Hotspot areas where the control of grit, floatables, and/or oil and grease are required

2. Gravity separators are typically used for areas less than 5 acres. It is recommended that the contributing area to any individual gravity separator be limited to 1 acre or less of impervious cover.
3. Gravity separator systems can be installed in almost any soil or terrain. Since these devices are underground, appearance is not an issue and public safety risks are low.
4. Gravity separators are flowrate-based devices. This contrasts with most other stormwater structural controls, which are sized based on capturing and treating a specific volume.
5. Gravity separator units are typically designed to bypass runoff flows in excess of the design flow rate. Some designs have built-in high flow bypass mechanisms. Other designs require a diversion structure or flow splitter ahead of the device in the drainage system. An adequate outfall must be provided.
6. The separation chamber should provide for three separate storage volumes:

   (1) A volume for separated oil storage

   (2) A volume for settleable solids accumulation at the bottom of the chamber

   (3) A volume required to give adequate flow-through detention time for separation of oil and sediment from the stormwater flow
7. The total wet storage of the gravity separator unit should be at least 400 cubic feet per contributing impervious acre.
8. The minimum depth of the permanent pools should be 4 feet.
9. Horizontal velocity through the separation chamber should be 1 to 3 ft/min or less. No velocities in the device should exceed the entrance velocity.
10. A trash rack should be included in the design to capture floating debris, preferably near the inlet chamber to prevent debris from becoming oil impregnated.
11. Ideally, a gravity separator design will provide an oil draw-off mechanism to a separate chamber or storage area.
12. Adequate maintenance access to each chamber must be provided for inspection and cleanout of a gravity separator unit.
13. Gravity separator units should be watertight to prevent possible groundwater contamination.
14. The design criteria and specifications of a proprietary gravity separator unit should be obtained from the manufacturer.

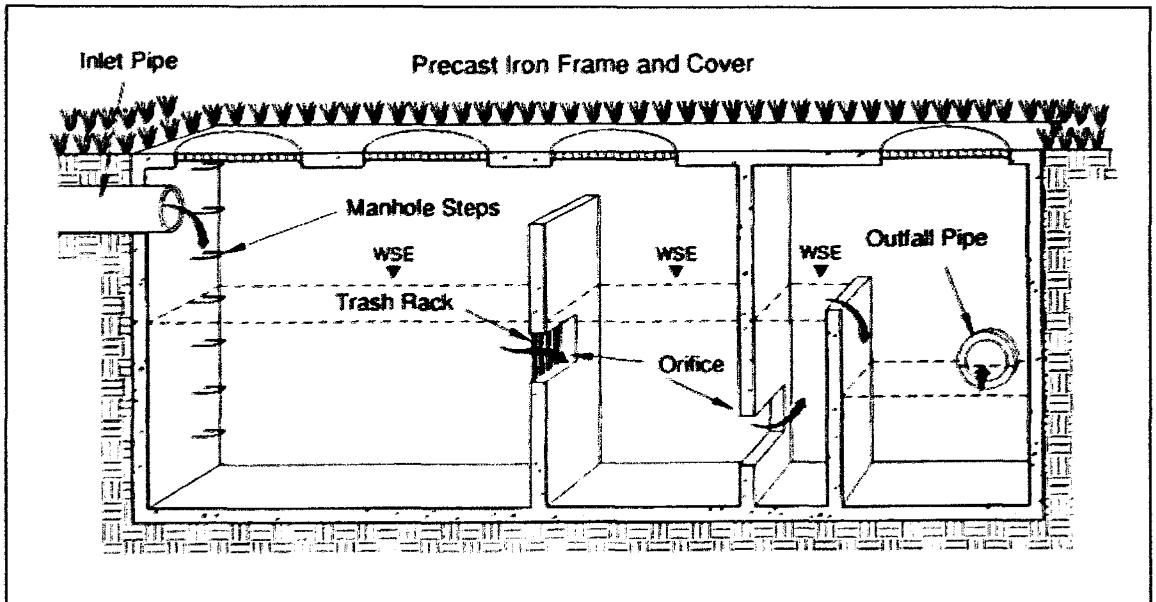
**As-Built Certification Considerations**

After the hydrodynamic device has been constructed, an as-built certification must be performed by a registered Professional Engineer and submitted to The City of Greenbrier. See Appendix B The as-built certification verifies that the BMP was installed as designed and approved.

**Maintenance**

Each BMP must have an Operations and Maintenance (O&M) agreement that is submitted to The City of Greenbrier for approval and is maintained and updated by the BMP owner. Refer to Appendix B for the O&M Agreement for bioretention areas. The O&M Agreement must be completed and submitted to The City of Greenbrier with the site plans. The O&M agreement is for the use of the BMP owner in performing routine inspections. The developer/owner is responsible for the cost of maintenance and annual inspections. The BMP owner must maintain and update the BMP operations and maintenance plan. At a minimum, the operations and maintenance plan must address:

1. Additional maintenance requirements for a proprietary system should be obtained from the manufacturer.
2. Proper disposal of oil, solids and floatables removed from the gravity separator must be ensured.




(Sources: NVRC, 1992)

**Figure 7.1 Schematics of Gravity (Oil-Grit) Separator**

### References

ARC, 2001. Georgia Stormwater Management Manual Volume 2 Technical Handbook.

CDM, 2000. Metropolitan Nashville and Davidson County Stormwater Management Manual Volume 4 Best Management Practices.

### Suggested Reading

California Storm Water Quality Task Force, 1993. California Storm Water Best Management Practice Handbooks.

# APPENDIX B

# AS-BUILT CERTIFICATION

# OPERATION AND MAINTENANCE AGREEMENT

# AS-BUILT CERTIFICATION

This is to certify that I am duly licensed to practice ________________________________
in the State of Tennessee, License # ______________.

I hereby certify that (project name)________________________________________________
Constructed under Grading Permit # _______________ has been constructed in accordance with the approved construction plans and is functional as designed.

- ☐ **Site grading including cut/fill**
- ☐ **Drainage System**
- ☐ **Detention Pond**
- ☐ **Final Stabilization**
- ☐ **Permanent StormWater Quality BMP(s)**

  Type: ______________________________
  ______________________________

______________________________
Signature

______________________________
Date

Seal

# OPERATION AND MAINTENANCE AGREEMENT (O&M)

I, ________________________________________, hereby acknowledge that I am the financially responsible party for maintenance and inspection of the permanent storm water quality treatment features for (project name) ______________________________________, located at (address)_____________________________________________________________________. I will be responsible for the performance of the required maintenance for each permanent storm water quality treatment feature, located on the above referenced site, as specified in the construction plans approved by City of Greenbrier.

___________________________________

Signature

___________________________________

Date

I, ________________________________________, a Notary Public for the State of _____, County of ____________________, do hereby certify that ________________________________ personally appeared before me this ____________ day of _________________, 20____, and acknowledge the due execution of the foregoing instrument.

Witness my hand and official seal,

___________________________________

Signature

Seal

My commission expires ________________________________.